MENU COSTS : AN OVERVIEW AND A STUDY WITHIN A STRATEGIC INTERACTION SETTING

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Abstract of the thesis

Chapter 1 presents the background to the development of macroeconomic models with "menu costs", i.e., the costs of adjusting nominal prices. The debate on microeconomic foundations of macroeconomics is introduced in Section 1. The theoretical basis of the «classical dichotomy» between real and nominal variables and the role of nominal imperfection for the failure of such dichotomy are briefly surveyed in Section 2 and 3, respectively. The "monetary illusion" assumption and its limits are presented in Section 4. An account of some potential sources of nominal imperfections concludes the chapter.

Chapter 2 deals with the New Keynesian microeconomic foundations of nominal rigidity. Section 1 introduces the key elements of New Keynesian microfoundations. In Section 2, the seminal 1985 paper by Mankiw is examined in some detail. It will be shown that small menu costs can cause "monetary" business cycles to have large welfare effects. The role of real rigidities in explaining nominal price stickiness is addressed in Section 3. The remaining part of the chapter focuses on dynamic models of menu costs.

Chapter 3 gives a quick overview of microeconomic studies on costly price adjustment. Section 1 outlines Barro (1972) and Sheshinski and Weiss (1977), where a monopoly optimal pricing policy is derived. In Section (2), an overview of recent game-theoretic frameworks with menu costs is given. It will be argued that these models fail to capture the theoretical essence of menu costs. The last part of the chapter deals with the issue of the empirical relevance of costly price adjustments.

Chapter 4 presents a theoretical study that can contribute to shed light into menu costs within a game-theoretic setting. Section 1 introduces the issue. In Section 2, a Bertrand duopoly model with menu costs is set up in order to derive the duopolists' best response to a nominal shock. The main findings are expounded in Section 3. A duopoly nominal price adjustment rule will be derived. This turns out to be contingent to the sign of the nominal shock. Situations of multiple equilibria, both symmetric and asymmetric, can also arise.

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Introduction

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Introduction

The existence of some type of nominal frictions within a free-market economy, where economic agents behave rationally and money is used as medium of exchange, represents a theoretical justification for explaining why the fictitious Walrasian auctioneer may not be able to ensure a stable full-employment equilibrium. Over the 1980s, these nominal frictions have taken the form of costly nominal price adjustments. Purpose of this thesis is to survey both the macroeconomic as well as the microeconomic literature concerning the costs of adjusting nominal prices. Moreover, it aims to shed some light on how the implications of the existence of costly nominal price adjustments can be affected by different type of market structures, notably by a strategically-interactive setting.

The thesis is organised as follows.

Chapter 1 presents the background to the development (over the 1980s) of macroeconomic models with "menu costs", i.e., the costs of adjusting nominal prices. The debate on microeconomic foundations of macroeconomics, most notably of the real effects of money, is introduced in Section 1. The theoretical basis of the "classical dichotomy" between real and nominal variables is briefly surveyed in Section 2. It will be shown that within the neoclassical framework money turns out to be effectless (i.e., neutral) on real magnitudes. Section 3 deals with the conditions needed for the classical dichotomy to fail. Specifically, the role of nominal imperfections will be outlined. The "monetary illusion" assumption and its limits are presented in Section 4. An account of some potential sources of nominal imperfections concludes the chapter. Section 5 deals with imperfect information regarding prices. This leads to money misperception and, consequently, to money non-neutrality. Section 6 focuses on nominal friction in the form of long-term contracts that causes nominal wages to be rigid.

Chapter 2 deals with the New Keynesian microeconomic foundations of nominal rigidity. Specifically, it will be shown how nominal price inertia can be derived from individual optimising behaviour. Section 1 briefly introduces the key elements of New Keynesian microfoundations, namely (i) imperfectly competitive goods markets, (ii) small nominal friction, and (iii) some type of real rigidities. In Section 2, the seminal 1985 paper by Mankiw is examined in some detail. It will be shown that small menu costs, in principle, can cause "monetary" business cycles to have large welfare effects. The role of real rigidities in explaining nominal price stickiness is addressed in Section 3, where a short account of Ball and Romer (1989, 1990) will be given. Because of real rigidity, multiple symmetric equilibria in nominal price adjustments can also arise. In Section 4, I shall briefly consider the issue of price indexation. The remaining part of the chapter focuses on dynamic models of menu costs. In Section 5, the main features of time-dependent and state-dependent pricing rules are surveyed. Section 6 outlines the Caplin and Spulber 1987 model and its main implications.

Chapter 3 gives a quick overview of microeconomic studies on costly price adjustment. Most of them focus either on monopoly or on monopolistic competition. Attempts to analyse menu costs within a strategically interactive setting are rare indeed and typically consider real rather than nominal shocks. Section 1 outlines Barro (1972) and Sheshinski and Weiss (1977). It will be shown that the optimal pricing policy for a monopolist faced with costly price adjustments and a continuously increasing rate of inflation takes the form of an (S,s) rule. In Section (2), an overview of recent game-theoretic frameworks with menu costs is given. It will be argued that these models fail to capture the theoretical essence of menu costs. The last part of the chapter deals with the issue of the empirical relevance of costly price adjustments.

Chapter 4 presents a theoretical study that can contribute to shed light into menu costs within a game-theoretic setting. Section 1 briefly introduces the issue. In Section 2, a Bertrand duopoly model with menu costs is set up in order to derive the duopolists' best response to a nominal shock. To start with, a generic demand structure for each duopolist is considered (Section 2.1). It will be shown that firm-specific nominal price rigidity can occur even when menu costs are set equal to zero. A specific functional form is chosen in Section 2.2. The main findings are expounded in Section 3 where the cases of zero and of strictly positive menu costs are in turn outlined (Section 3.1 and 3.2, respectively). A duopoly nominal price adjustment rule will be derived. This turns out to be asymmetric, i.e., contingent to the sign of the nominal shock. Situations of multiple equilibria, both symmetric and asymmetric, can also arise.

CHAPTER 1:
Money non-neutrality and microeconomic principles

Money non-neutrality and microeconomic principles

This chapter presents the background to the development (over the 1980s) of macroeconomic models with "menu costs", i.e., the costs of adjusting nominal prices. The debate on microeconomic foundations of macroeconomics, most notably of the real effects of money, is introduced in Section 1. The theoretical basis of the "classical dichotomy" between real and nominal variables is briefly surveyed in Section 2. It will be shown that within the neoclassical framework money turns out to be effectless (i.e., neutral) on real magnitudes. Section 3 deals with the conditions needed for the classical dichotomy to fail. Specifically, the role of nominal imperfections will be outlined. The "monetary illusion" assumption and its limits are presented in Section 4. An account of some potential sources of nominal imperfections concludes the chapter. Section 5 deals with imperfect information regarding prices. This leads to money misperception and, consequently, to money non-neutrality. Section 6 focuses on nominal friction in the form of long-term contracts that causes nominal wages to be rigid.

1. Introduction

The role of money within the market economy is a long-disputed issue in economics[1]. The matter of controversy is, precisely, whether or not monetary, i.e., nominal, changes can affect real magnitudes such as output and employment. If so, money is said to be non-neutral. Otherwise, it is qualified as neutral. In this latter case, changes in the money stock affect only nominal variables and a dichotomy (the so-called classical dichotomy) between the real and the nominal side of the economy emerges.

At least since World War II the debate on the sensitivity of real variables to monetary changes has become relevant to the research on economic fluctuations[2]. In particular,

[1] Money was an object of dispute well prior to the publication of J.M. Keynes' 1936 book *The General Theory of Employment, Interest and Money*. For a brief and enjoyable historical account see Galbraith (1987), Chapter 12.

[2] See McCallum (1988), where post-war developments in business cycle theories are surveyed. For surveys on business cycles theories see also Gordon (1981, 1990), McCallum (1986), Silvestre (1993).

the non-neutrality of money is at the heart of a class of business cycle models that account for the observed macroeconomic fluctuations as the result of exogenous[3] demand shocks (typically, monetary shocks). Hence the label of Monetary Business Cycle (MBC) models[4]. This class of models embraces both the theoretical contributions by Keynesian[5] or non-market-clearing macroeconomists, as well as the theoretical contributions by New Classical or equilibrium macroeconomists of the "First Generation"[6]. In passing, the non-neutrality of money (in the short term) is the only common feature shared by the two competing schools of macroeconomic thought[7].

According to MBC theorists, economic fluctuations are (mainly) demand-driven. Specifically, aggregate supply (AS) deviates from its natural, i.e., trend, growth rate primarily because of exogenous disturbances affecting the nominal aggregate demand (AD)[8]. Such disturbances are usually taken to be of monetary nature[9]. Since

[3] The volatility of output and employment is commonly explained as the result of shocks that are exogenous to the economic system. There are, indeed, alternative business cycle models where disturbances are taken as endogenous. For an empirical evaluation of the currently prevalent models of exogenously-driven economic business cycles see Cochrane (1994). References on alternative theories with endogenous shocks, can be found therein.

[4] This label is used to emphasise the contrast with Real Business Cycle (RBC) models, where money is neutral and economic fluctuations are initiated by real rather than nominal shocks. These shocks typically affect technology. According to RBC economists, the main source of output volatility is located in the supply side of the economy. In a fairly rough fashion, RBC theories can be qualified as theories of supply-driven fluctuations. While MBC theories as theories of demand-driven fluctuations. RBC models are surveyed in McCallum (1989), and Plosser (1989). For an evaluation of RBC models from a «New Keynesian perspective» see Mankiw (1989).

[5] By Keynesian macroeconomics I mean that group of theories urging stabilisation policy. As the self-equilibrating market mechanism is subject to failures, policy-makers' intervention is highly recommended to ensure stable growth.

[6] The "First Generation" title aims to distinguish the 1970s equilibrium approach to the analysis of macroeconomic fluctuations from its later variant, namely the RBC approach, which R.J. Barro qualified as «Second Generation of New Classical macroeconomics». See Barro (1989), where the main departures of the Second Generation from the early New Classical macroeconomics are outlined.

[7] See McCallum (1988), p. 459.

[8] By nominal aggregate demand it is meant the schedule in the price – real income plane derived from the Hicksian IS-LM curves. Specifically, it represents the locus of intersection points of the IS-LM curves at different price levels. See Stevenson *et al.* (1988), Chapter 1 and 7, for details on the aggregate demand.

[9] An exogenous nominal shock can be any disturbance affecting one (or more) of the AD exogenous components (money supply, government expenditure, net exports). Yet, much of the research has focused on disturbances to the money supply. As pointed out by Blanchard (1990), «[t]his is not because money is the major source of movements in output. Rather, it is because economic theory does not lead us to expect such effects». See Blanchard (1990), p. 780; see also Blanchard and Fischer (1989), p. 376 (footnote 9).

shocks (are expected to) enter into and propagate across the economy through the nominal AD, causality runs from AD, which is exogenously determined, to AS[10]. MBC macroeconomists' analysis is therefore focused on the determinants of the AS, notably on the behaviour of prices. As it will become clear soon, it is price behaviour that matters in establishing whether money is neutral or not.

Although the controversy on money and, accordingly, on the main source of business cycles involves both theory and facts, I shall concentrate only on the former, leaving the empirical quarrel aside[11]. Scope of the chapter is to introduce the theoretical conundrum of explaining money non-neutrality in terms of choices made by rational, i.e., objective maximising, decision makers[12]. As clearly pointed out by Andersen (1994), «[t]he reason for stressing the need to base models on optimizing agents is to impose the discipline that explanations should be consistent with systematic behaviour». Any economic phenomenon can be justified by coincidences or rules of thumb. No doubt, however, that if it can be effectively described «as the result of systematic behaviour driven by economic incentives», we will have «a more robust explanation and the possibility of analysing how this behaviour is influenced by change in the environment, ...»[13].

Before concluding this introduction, it is worthwhile to emphasise that any attempt of providing microeconomic foundations to macroeconomics (in the sense given above) implicitly assumes that aggregates obey microeconomic principles. Thus, the behaviour of economy as a whole can *always* be well approximated by aggregating across individual behaviours. According to this approach, which appears to have been dominant in the development of macroeconomics over the last three decades,

[10] The possible channels of feedback from prices to nominal AD (e.g., the real balance effect or the intertemporal substitution of consumption due to expectations on inflation) are ignored, since they are of secondary importance with respect to the matter I am dealing with.

[11] The most striking fact that seems to be against the (short-term) neutrality of money is the observed «Output-Inflation Trade-off». That is, the Phillips curve-type relation between output (employment) and inflation. Those who, nowadays, advocate the idea of money neutrality, namely the RBC theorists, resort to the "reverse causation" to justify the trade-off. It is not money that causes output to vary, but *vice versa*. See, among others, Barro (1989).

[12] For details on the debate on the microeconomic foundations of macroeconomics see Mankiw (1990), Blanchard (1990), Romer (1996), Chapter 6. An interesting methodological appraisal of the attempts to underpin «descriptive macroeconomics» with microeconomic, i.e., theoretical, foundations is provided by Janssen (1991). An interesting reading is also Lucas (1977).

any explanation of macroeconomic events that fails to fit the objective-maximising postulate must be dismissed because of its alleged inconsistency with microeconomic principles[14]. Quoting J. Tobin, «[m]any contemporary theorists cannot believe any theory that implies socially irrational market failures. They suspect that individual irrationalities are lurking somewhere in the theory»[15].

2. The neoclassical paradigm and the neutrality of money

The advocates of the neutrality of money can rely on a well established theoretical apparatus; namely the internally consistent paradigm that formalises the neoclassical idea of how the free-market economic system works. In a world where economic agents are supposed to be fully rational and informed and prices fully flexible, money turns out to be (approximately) neutral[16].

Rationality and perfect information ensure that individuals do not forego any perceived gain from trade. Price flexibility guarantees that all markets clear at any time: as soon as demand and supply differ, the relevant prices promptly adjust as to restore the identity. Such self-equilibrating market mechanism is known as the "Law of Supply and Demand". The behaviour of the economy as a whole is derived by aggregating across markets and microeconomic units, i.e., individuals and firms. As the market-clearance condition is continuously and everywhere met, the economy is (expected to be) always at its full employment equilibrium. That is, there are no idle resources that could be somehow activated. In particular, the labour market-clearing level of employment determines the level of aggregate output, AS. Whereas total expenditure, i.e., nominal AD, passively follows suit as predicted by the Say's Law[17].

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[13] See Andersen (1994), p. 7.

[14] In general, any explanation of economic facts that clashes with the postulate of optimising behaviour undermines the aspiration of making economics a body of analytical tools as internally consistent as possible. G.A. Akerlof and J.L. Yellen, among others, raise however some doubts on this «esthetic» aspiration. See Akerlof and Yellen (1987), p. 137.

[15] See Tobin (1993), p. 47. See also Janssen (1991), p. 619.

[16] In R.J. Barro's words «the neoclassical framework [...] has a strong tendency to generate a close approximation to monetary neutrality». See Barro (1989), p. 2, and Blanchard (1990), p. 780. For a detailed justification for why money can have real, if marginal, effects also within the neoclassical framework see Stevenson *et al.* (1988), pp. 35-8.

[17] According to Say's law, supply creates its own demand, i.e., «the overall activity of production generates purchasing power (distributes real income) which is inevitably spent in buying the real

Since resources are fully employed (vertical AS), movements in AD *in no way* can affect the aggregate level of output.

Figure 1, where the AS schedule is plotted in the price - output plane, captures the key features of the neoclassical macromodel[18]. As pointed out, real variables remain unaffected by nominal movements. Any change in the money stock (represented in Figure 1 by a shift of AD, from AD_1 to AD_2) only produces a proportional change in the general price level, *P*, leaving the full-employment equilibrium level of aggregate income, y^*, fixed.

FIGURE 1 (at the end of the chapter).

3. Nominal imperfections and money non-neutrality

It is often argued that «[a]ny microeconomic basis for failure of the classical dichotomy requires some kind of nominal imperfection; otherwise, a purely nominal disturbance leaves the real equilibrium (or the set of real equilibria) unchanged»[19]. This argument is based on the property of zero-degree homogeneity in all money variables held by the individual demand and supply functions. The property states that in a perfectly competitive world with full information and no friction, i.e., in a Walrasian world, if all money variables vary by the same proportion, δ, an optimising, agent will not amend his/her quantity decisions. Demand and supply (in real terms) remain therefore unchanged. Hence the dictum that monetary magnitudes are immaterial for rational agents' real decisions. Formally[20], such property reads

(1) $x_i^j(\delta \mathbf{p}, \delta w) = \delta^0 x_i^j(\mathbf{p}, w)$,

where subscript i refers to the individual price-taking consumer (producer); x_i^j denotes the demand of i for the final good (factor) j, $\mathbf{p}$ the vector of prices in the final good (input) market, and w the monetary income of i (the scalar price of output

output delivered by that activity». The main implication of Say's law is that savings always equal investment. See Benassi *et al.* (1994), p. 6.

[18] For details see Stevenson *et al.* (1988), pp. 28-44.

[19] See Romer (1993), p. 7.

[20] See Varian (1992), p. 31.

produced by i). In passing, notice that δ can be regarded as a change in the money stock. Let me remark that the zero-degree homogeneity of demand and supply functions is not assumed. Rather, it stems from the solution of utility and profit maximisation problems according to the traditional (i.e., neoclassical) microeconomic framework of individual choices.

As (1) describes the behaviour of a rational economic agent in a Walrasian world, some departures from this "perfect" world are needed for its breakdown and, consequently, for failure of the classical dichotomy[21]. These departures are often called nominal imperfections. The use of the adjective nominal serves to remark that such imperfections cause nominal movements to have real effects. It is important not to confuse nominal with real imperfections. Both identify departures from the Walrasian world. Nonetheless, only the former generate money non-neutrality[22].

In the literature nominal imperfections usually take the form either of (i) money misperception or of (ii) rigid nominal wages and/or prices. Models with money misperception belong to equilibrium macroeconomics. Models with nominal rigidities belong to non-market clearing macroeconomics. As for the sources of these two types of nominal imperfections, since the early 1970s different suggestions have been put forward. In Sections 5 and 6 I shall deal with money misperception due to imperfect information and nominal (wage) rigidity due to long-term wage contracts, respectively. While the next Chapter will be focused on nominal (price) rigidity due to costly price adjustments. First, however, it is worthwhile considering the so-called "monetary illusion" assumption on which models of money non-neutrality were more ore less explicitly based before the early 1970s[23].

4. The monetary illusion assumption

[21] Failure of the zero-degree homogeneity property is a necessary condition for money to have real effects at the microeconomic level. Nonetheless, it may not be sufficient at the macroeconomic level. Consider the following analogy. Zero (i.e., money neutrality) is the result of the sum not only of zeros (i.e., firm-specific nominal price flexibility), but also of non-zero numbers (i.e., firm-specific nominal price rigidity). It means that the aggregation across individual price behaviours is far from straightforward. I shall return to this issue in the next Chapter, where an account of Caplin and Spulber (1987) will be given.

[22] See Romer (1993), p. 7.

According to the monetary illusion assumption, individuals attach special significance to nominal magnitudes. Notably, workers hardly accept cuts in their money wages. Thus, in case of a downwards monetary contraction nominal wage adjustments turn out to be sluggish, unlike nominal price adjustments, which instead are (supposed to be) full and prompt. As a result, the real wage, W/P (W and P denote the nominal average wage and the general price level, respectively) goes up and, consequently, output and employment decrease[24].

Models based on the monetary illusion assumption, if capable of generating the non-neutrality of money, nonetheless did not make clear why optimising economic agents, who in the absence of nominal imperfections should care only about real magnitudes, can be victims of monetary illusion. Over the 1960s the issue did not appear at the front of the MBC theorists' research agenda[25]. In retrospect, it can be said, as suggested by Blanchard (1990)[26], that the existence of a «reliable empirical relation» between nominal and real variables (i.e., the Phillips curve-type trade-off between output and inflation) probably made appear less urgent the need for a rigorous justification of the real effects of money.

Only at the beginning of the 1970s, when economic events strongly contradicted the prediction based on the «unadorned Phillips curve»[27] and a long period of high inflation and high unemployment (i.e., stagflation) occurred, it was no longer possible to ignore «the chasm between [traditional] microeconomic principles and macroeconomic practice»[28]. The time was ripe for trying to develop macroeconomic models of money non-neutrality grounded on firm microeconomic foundations[29].

5. Imperfect information and money misperception

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[23] See Blanchard (1990), p. 783

[24] The monetary illusion assumption points towards countercyclical real wages, i.e., output and real wages would move in opposite directions over the cycle. Yet, empirical studies suggest that real wage movements are acyclical or, at most, procyclical, see Mankiw (1990), p. 1656-7.

[25] See Blanchard (1990), p. 784 and Mankiw (1990), p. 1647-48.

[26] See Blanchard (1990), p. 784.

[27] It is the first version of the Phillips curve-type relation, where expectations are ignored. The later version is the Rationale-Expectation-Augmented Phillips curve, see Mankiw (1990), p. 1647.

[28] See Mankiw (1990), pp. 1647.

The first attempt to explain money non-neutrality in terms of individual rational choices was made by R. Lucas[30], the leading figure of the New Classical macroeconomists of the first generation[31]. In Lucas (1972), the classical dichotomy breaks down because of monetary misperception due to a lack of information regarding the aggregate price level. The key ingredients of the model are (i) imperfect information and (ii) rational expectations. The former introduces uncertainty in an otherwise Walrasian framework. The Rational Expectation Hypothesis (REH) ensures that individuals form their expectations about the future using efficiently all the available information at the time of expectation formation. The REH, to be sure, does not rule out expectational errors. As rational agents cannot predict the unpredictable, expectations may turn out to be wrong. Nonetheless, if this happens, it will be because of completely unforeseeable (i.e., non-systematic) events, occurred after expectations have been formed.

The intuition behind Lucas (1972) is the following[32]. Consider an economy where individuals live in different islands between which information flows are costly[33]. Each producer can observe only price movements in his/her own price and in the prices of his/her co-islanders. Whereas movements in other islands' prices and in the general price level become known only after some time lags. Consequently, a price-taking producer cannot distinguish whether unanticipated changes in his/her own good's price reflects movements in relative prices, which would justify quantity adjustments, or movements in the aggregate price level, which should be irrelevant for rational agents. The producer, in other words, becomes promptly aware of the occurrence of a shock. But he/she cannot immediately establish its nature. Now, if both real and nominal disturbances are random walk, the producer's optimal response to the observed change in his/her price will be to attribute such change partly to unexpected movements in the aggregate price level (i.e., to a nominal shock)

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[29] The need for building macroeconomic theory based on solid microeconomic foundations was urged by E. Phelps and M. Friedman at the end of 1960s.

[30] See McCallum (1988), p. 463.

[31] For an overview of New Classical macroeconomics see, among others, van Zijp (1993), Part II.

[32] For details see Lucas (1977), Gordon (1981) pp. 506-9, Blanchard (1990), pp. 795-6, and Romer (1996), pp. 243-50.

[33] The "island parable" was first used by E. Phelps; see Phelps (1970), p. 6.

and partly to unexpected movements in relative prices (i.e., to a real shock). As a result, he/she will always revise his/her quantity decisions, even when changes in individual prices mimic movements in the aggregate price level. Hence the failure of the classical dichotomy.

Under the REH, only completely unpredictable events surprise rational agents. As systematic nominal movements in no way can be misperceived, they turn out to be neutral. This result was taken by New classical macroeconomists as a strong clue against Keynesians' recommendations for systematic stabilisation policy. It was argued that any attempt to stimulate the economy through countercyclical monetary measures that are applied in a uniform and consistent fashion ends up with a proportional *expected* increase in the level of inflation, leaving the real side of the economy unchanged. Thus, the REH alone appeared to be able «to undo many of the central results of traditional Keynesian theory, most notably the stabilizing powers of aggregate demand policy»[34]. As it will be shown in the next Section, however, the introduction of nominal rigidities is enough to invalidate the New classical policy ineffectiveness proposition.

Despite its widespread popularity over the 1970s[35], the money misperception argument was later dismissed even by many adherents to the New classical macroeconomics[36]. The main reason for its repudiation was the implausibility of its crucial assumption, namely that individual are unable to observe current nominal magnitudes. As pointed out among others by McCallum (1988), at least in modern economies, «information regarding aggregate nominal magnitudes - money supply and price index figures - is available to the public both promptly and cheaply»[37]. Thus, it is hard to believe that rational individuals can significantly misperceive movements in the aggregate price level. Unless they are «equipped with a pair of blinders that arbitrarily cuts [them] off from information printed in the daily

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[34] See Romer (1996), p. 256.

[35] See Mankiw (1990), p. 1652.

[36] See McCallum (1988), p. 464; Blanchard (1990), p 801; Mankiw (1990), p. 1653. As mentioned, many members of the New classical macroeconomics turn their attention to real shocks.

[37] See McCallum (1988), p464.

newspaper on aggregate variables like interest rates, price indexes and the money supply»[38].

6. Long-term contracts and nominal (wage) rigidity

Long-term nominal contract models, based on Fischer 1977 and Taylor 1980 works[39], represent the non-market-clearing reply to the theoretical attack made by New classical macroeconomists. The objective was to prove that systematic monetary policy can effectively stabilise the economy even under the REH.

Unlike Lucas (1972), where the Walrasian auctioneer makes sure that prices are flexible in all markets, long-term contract models are characterised by (i) price-setting agents in the labour market and (ii) nominal wage rigidity due to long-term contracts. Specifically, wage-setters (are supposed to) set nominal wages in contracts that are revised only at fixed intervals of time[40]. In line with the REH, when nominal wages are set and/or revised economic agents take into account any future systematic monetary movements, such as expected inflation. Despite that, monetary policies can effectively stabilise the economy because wage adjustments to monetary shocks occur discretely rather than continuously[41].

A simple way to grasp the intuition behind this result is the following[42]. Let τ denote any fixed interval of time wage contracts remain in effect. The optimal level of aggregate output over τ, y_τ, can be defined by

(2) $$y_\tau = -\frac{W_{\tau 0}}{P_\tau},$$

where, $W_{\tau 0}$ is the (average) nominal wage optimally set at the beginning of τ and P_τ is the aggregate price level over τ. Expression (2) implies a negative relation between the level of output and the (average) real wage, $W_{\tau 0}/P_\tau$.

[38] See Gordon (1981), p. 494.

[39] For details see Blanchard (1990), pp. 803-6, and Romer (1996), 256-73.

[40] It is also assumed that wage revisions are staggered across the economy. Staggering assumption is important in terms of persistency in the real effects of money. But it is not necessary for money non-neutrality to occur, nor for stabilisation policy to be effective. That is why I shall ignore it here.

[41] Wage adjustments take place only when contracts are revised.

[42] For details see, among others, Blanchard (1990), pp. 803-6, and Romer (1996), pp. 262-265.

Goods markets are (supposed to be) perfectly competitive. So, P_τ is fully flexible and can be regarded as an indicator of the money stock.

In $\tau 0$ wage-setters determine their nominal wages according to the following rule:

(3) $\quad W_{\tau 0} = E_{\tau 0}[P_\tau]$,

where expectations, $E[\cdot]$, are formed rationally.

The dynamics of the aggregate price level over τ is

(4) $\quad P_\tau = f(m) + u_\tau$,

where m is a predictable nominal component under the control of policy-makers, and u_τ represents a stochastic (i.e., non-systematic) non-policy nominal disturbance. As expectations are formed rationally, if $u_\tau = 0$, then $E_{\tau 0}[P_\tau] = P_\tau$. Consequently, the aggregate level of output remain fixed at its optimal level, given in (2). But, if $u_\tau \neq 0$, i.e., if there is a nominal shock, true and expected values of the aggregate price level will differ and the pre-set nominal wage, $W_{\tau 0}$, will be no longer optimal. That means that the aggregate level of output deviates from its optimal level.

According to (2), the equilibrium output can be restored (i.e., the nominal shock can be neutralised) either by varying the numerator, $W_{\tau 0}$, or by varying the denominator, P_τ. Since wage-setters can adjust their pre-set nominal wages only at the end of τ, the former option is not promptly available. It is the aggregate price level that must take up the task. According to (4), this implies an active role of monetary policy. Specifically, policy-makers can intervene to vary m as to offset the change in P_τ due to the unexpected monetary shock.

It is worthwhile noting that the idea behind the policy ineffectiveness proposition, namely that any systematic monetary measure does not surprise rational agents, still holds. Yet, as nominal wages are not revised continuously, monetary policy can effectively be used, if necessary, to stabilise the economy in the interval of time between two subsequent wage revisions.

6.1 Nominal rigidity: a missing link

Long-term contract models succeeded in proving that non-passive systematic stabilisation policies are compatible with the REH. To the extent that nominal wages (or prices) do not adjust promptly in response to unexpected monetary shocks, there is always room for policy-makers' intervention in the Keynesian spirit, regardless of whether economic agents form their expectations efficiently or not. Nonetheless, these models neglected to justify the existence of long-term contracts in terms of individual rational choices.

Allowed that long-term nominal contracts are the source of nominal rigidity and, consequently, of the highly undesirable volatility of output and employment, why should rational firms and workers agree to sign such "bad" contracts? Why not to choose different types of contracts as to neutralise (nominally-driven) economic fluctuations? Just like in the models based on the monetary illusion assumption, also in the long-term contract models nominal (wage) rigidity and the related real effects of money appeared to be the result of non-optimising behaviour. As if economic agents were willing to "leave $500 bills on the sidewalk"[43].

At the beginning of the 1980s, the microeconomic foundations of nominal rigidity were still a missing link in the non-market clearing theoretical system.

[43] It paraphrases a famous quip by R. Lucas against models with nominal rigidities, see Ball and Mankiw (1994), p. 137.

FIGURE 1

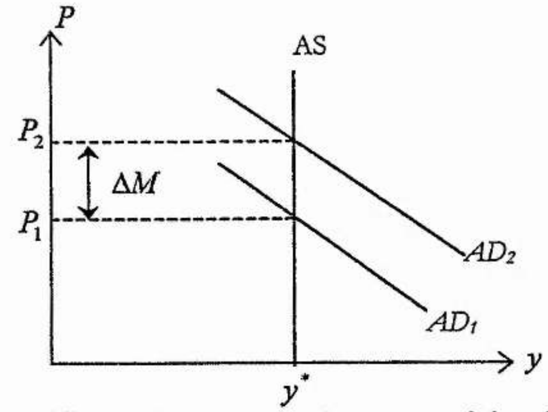

Figure 1: neoclassical macromodel and money neutrality

P : aggregate price level;

y^* : full-employment equilibrium level of aggregate output;

ΔM : change in the money stock.

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CHAPTER 2:

Nominal rigidity and New Keynesian microfoundations

Nominal rigidity and New Keynesian microfoundations

This chapter deals with the New Keynesian microeconomic foundations of nominal rigidity. Specifically, it will be shown how nominal price inertia can be derived from individual optimising behaviour. Section 1 briefly introduces the key elements of New Keynesian microfoundations, namely (i) imperfectly competitive goods markets, (ii) small nominal friction, and (iii) some type of real rigidities. In Section 2, the seminal 1985 paper by Mankiw is examined in some detail. It will be shown that small menu costs, in principle, can cause "monetary" business cycles to have large welfare effects. The role of real rigidities in explaining nominal price stickiness is addressed in Section 3, where a short account of Ball and Romer (1989, 1990) will be given. Because of real rigidity, multiple symmetric equilibria in nominal price adjustments can also arise. In Section 4, I shall briefly consider the issue of price indexation. The remaining part of the chapter focuses on dynamic models of menu costs. In Section 5, the main features of time-dependent and state-dependent pricing rules are surveyed. Section 6 outlines the Caplin and Spulber 1987 model and its main implications.

1. Introduction

At the beginning of the 1980s, Keynesian economics still lacked satisfactory microeconomic foundations[1]. The missing link was some justification that could reconcile the postulate of individual optimising behaviour, which is central in the «orthodox» economic theory, with nominal rigidities, which are crucial in the (new) Keynesian theory of economic fluctuations[2].

Over the 1980s, the "frustration" arising from the shortcomings of the "Old Keynesian"[3] attempts to solve the puzzle led some economists to shift attention to

[1] See Ball *et al.* (1988), p. 1.

[2] As mentioned in the previous Chapter, there is not a general consensus on this point among Keynesian economists.

[3] See Mankiw (1987), p.105.

imperfections in the goods rather than in the labour market[4]. It was the first step towards the creation of a theoretical apparatus later labelled as New Keynesian economics[5]. Among the many contributions aimed at providing New Keynesian microfoundations, the papers by Mankiw (1985) and Ball and Romer (1989, 1990) are worthy of particular attention[6]. The former shows that small nominal frictions at the level of individual rational firms can *in principle* bring about price rigidity at the aggregate level[7], which, in turn, cause money to have large, socially undesirable real effects. The latter prove that real rigidities, along with small menu costs, make Mankiw's conclusions much more plausible. Thus, the missing link seems to have been found in the combination of three key factors: (i) imperfectly competitive goods markets, (ii) small barriers in nominal adjustments at the microeconomic level (mainly in the form of costly price adjustments) and (iii) real rigidities.

2. Menu cost, nominal rigidity, and social welfare losses

It took some time to settle the controversy surrounding the microeconomics of nominal rigidity[8]. The merit of Mankiw (1985) was precisely to make breakthroughs in an area that at the time seemed to be highly controversial[9]. The central postulate of the model is that price adjustments are costly: price-setters can change their quoted

[4] «There are at least three major, well-known problems with the view that nominal wage inflexibility is crucial to understanding economic fluctuations. The first is that if nominal wage contracts are responsible for large and inefficient fluctuations in employment, then rational workers should not agree to them. [...]. The second problem [...] is that it is not obvious that observed nominal wages directly affect employment decisions. [...]. The final, and perhaps most serious, problem [...] is that real wages do not move over the business cycle as the theory predicts. According to this view, firms lay off workers in recession because labor costs are too high; prices have fallen but wages have not. In practice, however, real wages do not seem higher in recessions. To the extent that real wages appear cyclical at all, they seem procyclical». See Mankiw (1987), p.105-6.

[5] For an overview of New Keynesian economics see Rotemberg (1987). See also Mankiw and Romer (1991), Mankiw (1992), Benassi *et al.* (1994). A critical evaluation of New Keynesian economics is in Gordon (1990).

[6] Further theoretical contributions are those of Akerlof and Yellen (1985), Parkin (1986), and Blanchard and Kiyotaki (1987). A detailed bibliography can be found in Mankiw and Romer (1991).

[7] The difficulties arising from aggregating across price-setters are dealt with in a later section of the present Chapter.

[8] The criticism of lack in microeconomic foundations of Keynesian economics dates back to the early 1970s.

[9] An equally important paper is Akerlof and Yellen (1985), which appeared at the same time and in the same journal as Mankiw's. There, nominal frictions take the form of "near-rational" behaviour (i.e., a

nominal prices only by incurring a small fixed cost, the so-called menu cost[10]. Under this assumption, Mankiw shows that a profit-maximising monopoly firm can be better off by keeping its nominal price fixed rather than by amending it in response to a change in the prevailing state of the market due to a monetary shock. This behaviour, though optimal from a private viewpoint, can be socially inefficient and cause large welfare losses. Such findings, according to Mankiw, call for an active monetary policy, in the Keynesian spirit. It is worth examining Mankiw's model in some detail.

2.1. Assumptions in Mankiw (1985)

i) Profit-maximising monopolist producing a non-storable good. The assumption of non-storable goods allows to leave out problems concerning consumers' speculation on the timing of price movements[11]. As for the goods market imperfection, in Mankiw (1985) it takes the form of monopoly. In Chapter four, I shall set up a model where strategically interactive price-setters instead of a monopolist are considered[12].

ii) Economy with nominal price contracts. Specifically, goods are supplied at monetary prices that are set in advance of trade (i.e., pre-set) by contracts[13].

iii) Nominal price contracts are not contingent to any nominal index. Nominal price indexation is therefore ruled out. Notice that this is a key assumption. If nominal prices were contingent to some nominal index, aggregate price level would be fully flexible and money neutral. Some potential justifications for the lack of indexation in the economy are presented in Section 4 of this Chapter.

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small departure from full optimisation) instead of costly price adjustments. The findings are however similar to those in Mankiw (1985).

[10] In the literature menu costs are referred to as *fixed* costs of changing nominal prices. Here menu costs are given a broader interpretation. They are taken to mean costly price adjustments. So, menu costs identify both lump-sum as well as variable costs of changing nominal prices.

[11] Costly price adjustments with a storable good is examined in Benabou (1989).

[12] My model generates Mankiw (1985)'s results as a special case.

[13] Cf. Blinder and Mankiw (1984), type 3 economy.

iv) Changes in nominal prices are costly. Price-setters who amend their quoted nominal price incur a cost whose amount is fixed and does not depend on the size of price adjustment[14].

v) Input markets are perfectly competitive. Since the Walrasian auctioneer regulates these markets, nominal input prices are fully flexible[15]. As a result, they promptly and fully respond to nominal shocks[16].

vi) Quantity adjustments are costless[17]. Firms supply whatever quantity consumers demand when trade takes place. This implies that goods market clears at any time. Neither rationing nor overproduction occur. The burden of market clearing is taken by quantity rather than price adjustments.

vii) Changes in the state of nature are due only to nominal disturbances, notably to a one-off nominal shock. This assumption is in line with the (new) Keynesian belief that economic fluctuations are primary and mainly driven by exogenous demand shocks (e.g., changes in velocity of money). Real magnitudes, notably real prices, are therefore time-invariant[18]. Or rather, if movements in real variables occur, they will be due to money non-neutrality.

viii) The model adopts a static approach. Thus, the economy is initially in equilibrium.

---

[14] The case of variable costs of changing prices (i.e., the amount of menu costs increases with the size of price adjustment) is examined in Rotemberg (1982) and Konieczny (1993). Notice, however, that from a theoretical point of view lump-sum menu costs seem to be much more plausible. I shall revert to this point in the next chapter.

[15] Cf. Blinder and Mankiw (1984). See also Andersen (1994), p. 71.

This assumption testifies the breakdown between "Old" and New Keynesians. The former focus on labour market imperfection and nominal wage rigidity, whereas the latter on goods market imperfection and nominal price rigidity. Thus, the hypothesis of fully flexible nominal input prices aims to prove that nominal rigidities in labour market are not necessary for explaining business cycles.

[16] The case of rigid nominal prices in the input market as well as in the final goods market is examined both in Benassy (1987) and in Lucke (1995). In the latter, where a monopoly firm is considered, the findings do not confirm those of Mankiw (1985). In particular, no social externality arises.

[17] Were quantity adjustments costly, then the opportunity cost of keeping nominal prices fixed, i.e., of adjusting the quantity, would be affected also by the size of quantity adjustment costs. Costly quantity adjustments along with menu costs are examined in Andersen (1994) and (1995), and Lucke (1995). Quantity adjustment costs alone (instead of menu costs) are considered in Ginsburgh *et al.* (1991). Not surprisingly, the results are far from being consistent with each other.

[18] By time-invariant real magnitudes I mean that real shocks, such as changes in technology or in consumers' tastes, are absent.

2.2 The profit-maximising price in real and nominal terms

The demand function faced by the monopolist is:

$$(1) \qquad d = f\left(P/N\right) \equiv f(p) \qquad \frac{df}{dp} < 0,$$

where:

d is the demand for the non-storable final good;

P is the nominal price (henceforth capital letters will denote nominal magnitudes);

N is a nominal scale variable and denotes the (exogenous) level of aggregate demand. It may be any nominal indicator, such as the money stock or the level of GNP;

$P/N \equiv p$ is the (underlying) real price.

The inverse market demand function is

$$(2) \qquad P/N = h(d) \Rightarrow P = h(d) \cdot N,$$

where $h \equiv f^{-1}$.

The real cost function reads

$$(3) \qquad c = g(q) \qquad \frac{dg}{dq} \geq 0,$$

where:

c denotes the real total costs of production;

q is the level of output.

Multiplying both sides of (3) by N yields the production costs in nominal terms[19], i.e.,

$$(4) \qquad c \cdot N = g(q) \cdot N \Rightarrow C = g(q) \cdot N.$$

In case of constant average and marginal production costs[20], the cost function can be defined as follows

$$c = kq \Leftrightarrow C = kqN$$

where k is the constant marginal cost.

[19] It holds because of assumption (v).

[20] A more general cost function does not alter the results. See Mankiw (1985).

From (2) and (4), it is clear that both nominal prices, P, and nominal costs, C, move proportionally to N. In the absence of some nominal friction, the classical dichotomy holds and changes in N are fully reflected in changes in nominal magnitudes.

As the goods market is assumed to clear, output always equals demand. Thus, $d \equiv q$.

The nominal profit function is given by

(5) $\Pi(P) \equiv \Pi(N, p) = q \cdot (p - k) \cdot N$.

The corresponding real profit function reads

(6) $\pi\left(\frac{P}{N}\right) \equiv \pi(p) = q \cdot (p - k)$.

Under standard microeconomic assumptions, the profit function is strictly concave in p. So, there is only a single value of the real price for which the profit maximisation conditions are met. Letting $p_{MAX} \equiv \text{argmax } \pi(p)$, the corresponding optimal price in nominal terms reads $P_{MAX} = Np_{MAX}$. According to the inverse elasticity rule

(7) $\frac{p_{MAX} - k}{p_{MAX}} = \frac{1}{\varepsilon} \Leftrightarrow \frac{Np_{MAX} - Nk}{Np_{MAX}} = \frac{1}{\varepsilon}$,

where ε is the demand elasticity with respect to price.

From (7), the nominal profit maximising price yields

(8) $P_{MAX} \equiv Np_{MAX} = Nk \cdot \left(1 - \frac{1}{\varepsilon}\right)^{-1}$.

Equation (8) allows to see that the optimal nominal price is homogeneous of degree one in N. In other words, the ratio P_{MAX}/N is constant. This confirms that rational economic agents are concerned only with real variables. What really matters is the (underlying) real profit maximising price, p_{MAX}, which is independent from N and time-invariant, as there are no real disturbances (assumption (vii)).

Although economic agents are concerned with real magnitudes, prices are commonly set in monetary terms. Besides, the monopolist is assumed to quote his/her nominal profit-maximising price in advance of the trade. Thus, at the moment of price quotation (time 0), he/she must consider future realisations of N, namely the value taken by N when trade takes place (time 1). The nominal price quoted by the monopolist can be written as

(9) $\quad {}_0P_{MAX} = p_{MAX}N^e$,

where:

${}_0P_{MAX}$ is the *ex-ante* optimal nominal price;

N^e denotes monopolist's expectations concerning future realisation of N.

If the firm's expectations prove to be correct so that $N^e = N_1$ (N_1 denotes the nominal scale variable's realisation at the moment of trade), then ${}_0P_{MAX}$ will be also the *ex-post* nominal profit maximising price. In fact,

(10) $\quad N^e = N_1 \Leftrightarrow {}^{0}P_{MAX}\big/_{N_1} = p_{MAX}$.

Otherwise, if $N^e \neq N_1$ (i.e., a nominal shock has occurred), ${}_0P_{MAX}$ turns out to be no longer optimal, as the underlying real price, $p_1 \equiv {}_0P_{MAX}/N_1$, differs from p_{MAX},

(11) $\quad N^e \neq N_1 \Leftrightarrow {}^{0}P_{MAX}\big/_{N_1} \neq p_{MAX}$.

According to the nominal scale variable's realisation, the sub-optimal real price, p_1, may be larger or smaller than the optimal real price, p_{MAX}. Specifically,

for $N^e > N_1$ (i.e., in case of negative nominal shocks), then $p_1 > p_{MAX}$;

for $N^e < N_1$ (i.e., in case of positive nominal shocks), then $p_1 < p_{MAX}$.

2.3 The decision problem and the private incentive for rigidity

If a monetary shock has occurred (i.e., $N^e \neq N_1$), the price-setter will have to decide as whether to adjust or not his/her quoted nominal price in response to the shock. By choosing to adjust ${}_0P_{MAX}$, the price-setter incurs a fixed menu cost, z, and sets the nominal price in such a way that:

$$ {}^{1}P_{MAX}\big/_{N_1} = p_{MAX} $$

where ${}_1P_{MAX}$ is the new nominal price.

Moreover, as $p_i(t)$ is chosen as to maximise profit, also the optimal real price at time *t*, $p_i^*(t)$, is related to $M(t)-P(t)$.

It is important now to find a way to show the link between the optimal real price and aggregate output. For our purpose, it is enough to notice that

(20) $y(t)=[M(t)-P(t)]$,

where $y(t)$ refers to (the log of) total output.

Equation (20) is a simplified version of the aggregate demand equation[62]. It implies an inverse relationship between the aggregate price level and total output, which is the essential feature of aggregate demand[63].

Given equation (20), it is straightforward to express firm *i*'s real pricing rule at time *t* as a function of aggregate output

(21) $p_i^*(t)=p_i[y(t)]$.

Let me stress that the approach I have adopted to get (21) is just a shortcut. A thorough derivation of the relation between $p_i^*(t)$ and aggregate output requires a full specification of the model. However, it is beyond the scope of this section[64].

Following Romer (1996)[65], I write firm *i*'s real pricing rule as

(22) $p_i^*(t)=p_i^*[y(t)]\equiv c+\phi y(t)\Leftrightarrow c+\phi[M(t)-P(t)]$,

where:

c is a positive constant, whose value depends upon the features of consumer demand for the commodity produced by firm *i* (notably the elasticity of demand)[66].

ϕ is a parameter referring to the features of the technology function and its value is strictly positive[67].

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[61] See Caplin and Spulber (1987), p. 706.

[62] It reproduces in its essence the Fisher equation (with the velocity of money circulation normalised to unity).

[63] See Romer (1996), p. 245.

[64] What matters here it is to provide a formal proof of Caplin and Spulber (1987)'s result. For rigorous derivation of (25) see Blanchard and Kiyotaki (1987), which is usually taken as a benchmark for modelling macroeconomic models with imperfectly competitive markets. See also Caplin and Spulber (1987), and Romer (1996), pp 257-62.

[65] See Romer (1996), p. 260.

[66] Letting η be the elasticity of demand, then $c=\ln[\eta/(\eta-1)]$.

[67] See Romer (1996), p. 261-2.

It may be worthwhile remarking that expression (22) is nothing else but the inverse elasticity rule, which states that «a producer with market power sets price as a markup over marginal cost, with the size of the markup determined by the elasticity of demand».

For simplicity, c is normalised to zero.

Rearranging equation (22) according to the definition of real price provided earlier, it yields

(22a) $P_i^*(t)-P(t)=\phi[M(t)-P(t)] \Leftrightarrow P_i^*(t)=\phi M(t)+(1-\phi)P(t),$

where $P_i^*(t)$ is the optimal nominal price that firm i will quote at time t, if there are no menu costs.

Since $M(t)$ increases continuously over time, the pricing rule in (22a) implies continuous nominal price adjustments. Consequently, rational price-setters pursue it only in the absence of menu costs. Otherwise, if a fixed cost is incurred at each price change, they will prefer to amend their nominal prices only occasionally and with discrete jumps[68].

In Caplin and Spulber (1987), firms are supposed to pursue an (*S,s*) pricing policy, as introduced by Sheshinski and Weiss[69]. Specifically, whenever the nominal price is adjusted, it is set so that the underlying real price equals some target upper level, S (henceforth, s_U)[70]. This quoted nominal price is then kept fixed until the underlying real price has been eroded by money growth down to some trigger lower bound, s (henceforth s_L). At this point, nominal price is re-adjusted upwards; the real price returns to the upper limit; and the process begins anew. Notice that the size of nominal price adjustments is equal to $(s_U - s_L)$ and is constant over time. Moreover, nominal adjustments are always upwards (i.e., a one-sided pricing policy), as there is no deflation.

Now, consider a monetary expansion $\Delta M < (s_U - s_L)$ over some period of time, τ. We are interested in determining the resulting changes in the aggregate price level

[68] This issue will be addressed in Chapter three.

[69] The Sheshinski and Weiss 1977 paper will be outlined in Chapter three.

[70] In my notation capital letters refer to nominal magnitudes. Thus, to avoid confusion, s_U replaces S.

and output, ΔP and Δy. As for the change in the aggregate price level, we need to find the fraction of price-setters who respond to the monetary expansion by adjusting their nominal prices. According to the pricing policy described above, a firm (say, *i*) changes its nominal price at time *t* if $p_i(t) = s_L$, which is equivalent to

(23) $\quad P_i - P_i^*(t) = s_L \Leftrightarrow P_i - P_i^*(t-\tau) = s_L + \Delta P_i^*$,

where P_i is firm *i*'s (rigid) nominal price, currently in effect, and $P_i^*(t) \equiv P_i^*(t-\tau) + \Delta P_i^*$ is the optimal price firm *i* would quote at time *t* in case of zero menu costs.

Condition (23) implies that nominal prices are changed by those firms with initial (i.e., at time $t-\tau$) values of $P_i - P_i^*(t-\tau)$ that are equal to $s_L + \Delta P_i^*$. Since the initial values of $P_i - P_i^*(t-\tau)$ are supposed to be uniformly distributed over $(s_L, s_U]$, the fraction of price-setters to whom condition (23) applies is $\frac{\Delta P_i^*}{s_U - s_L}$. From (26b), ΔP_i^* can be expressed as $\phi\Delta M - (1-\phi)\Delta P$.

Bearing in mind that the size of each nominal price adjustment is $(s_U - s_L)$, it is easy to determine the change in the aggregate price index, which is given by

(24) $\quad \Delta P = \frac{\Delta P_i^*}{s_U - s_L}(s_U - s_L) = \phi\Delta M + (1-\phi)\Delta P$.

Equation (24) implies that $\Delta M = \Delta P$ and, taking into account (20), that $\Delta y = 0$. As a result, although firm-specific nominal prices adjust discretely to monetary expansions, the aggregate price level is fully flexible and money turns out to be neutral.

The intuition behind the result formalised in equation (24) is that firm-specific nominal price changes can have large impacts on the aggregate price level. Notably, the adjustment of those firms whose real prices have hit the trigger value s_L, fully compensates the rigidity arising from the behaviour of the non-adjusting firms.

Before concluding, it is worth pointing out that the neutrality of money in Caplin and Spulber (1987) cannot be taken as a general and robust result. As the themselves authors recognise[71], it strongly depends upon specific assumptions. In particular, the uniformity distribution of initial prices and, more importantly, the absence of deflation. If inflation is positive as well as negative, so that nominal adjustments are both upwards and downwards (i.e., two-sided pricing policy), then firm-specific nominal rigidity will generally lead to aggregate price inertia and money non-neutrality[72]. Thus, their model is an important contribution not so much for its (rather specific) results, but because it draws attention to the fact that it may be misleading to infer the features of the aggregate price level simply from firm-specific price decisions[73]. The issue of aggregation calls for specific and careful analyses.

[71] See Caplin and Spulber (1987), pp. 719-21.

[72] In Caplin and Leahy (1991) firms pursue a two-sided (*S,s*) price adjustment policy and money turns out to affect output.

[73] See Romer (1996), p. 276.

FIGURE 1

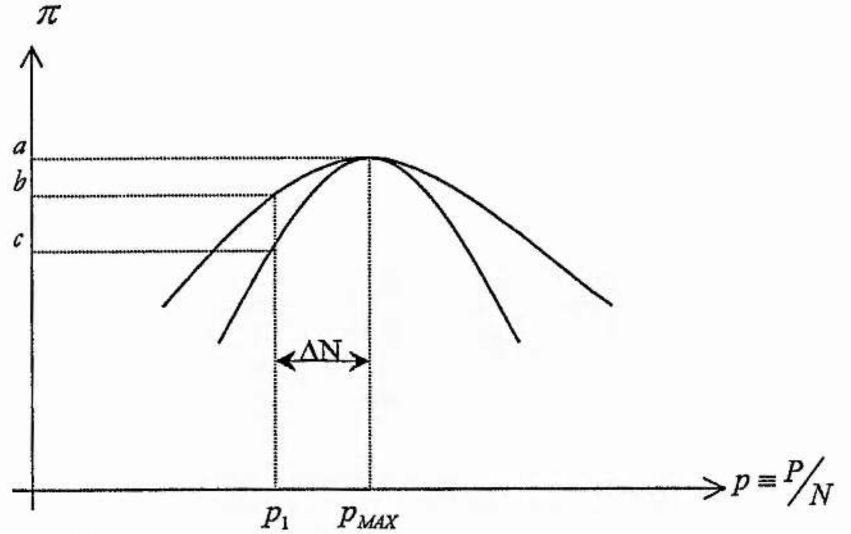

Figure 1: the role of the profit function's curvature

ΔN denotes the size of the (positive) nominal shock;

p_{MAX} is the real profit maximising price;

p_1 is the sub-optimal real price in case of nominal rigidity;

ab is the cost of rigidity in case of a relatively flat profit function;
ac is the cost of rigidity when the profit function is more sensitive to departure from the optimal price.

FIGURE 2

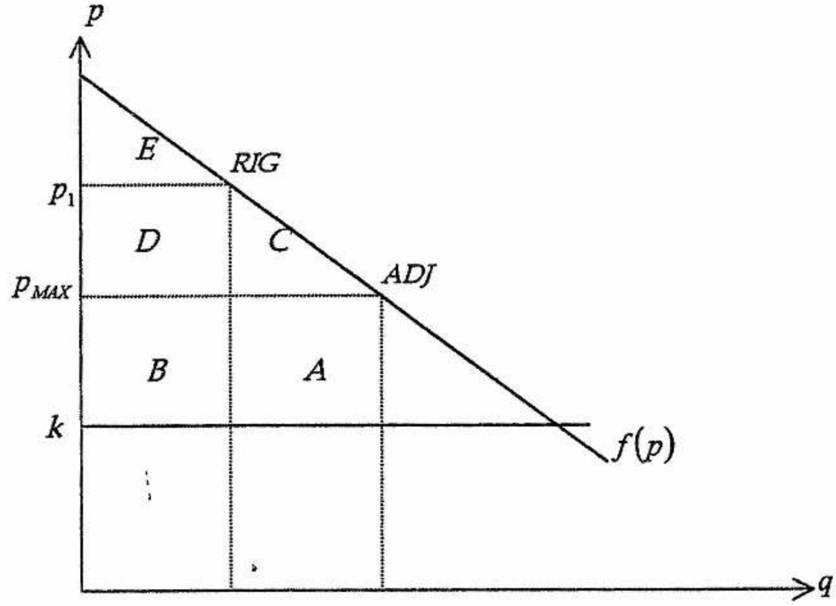

Figure 2: firm-specific nominal price rigidity and social welfare

FIGURE 3

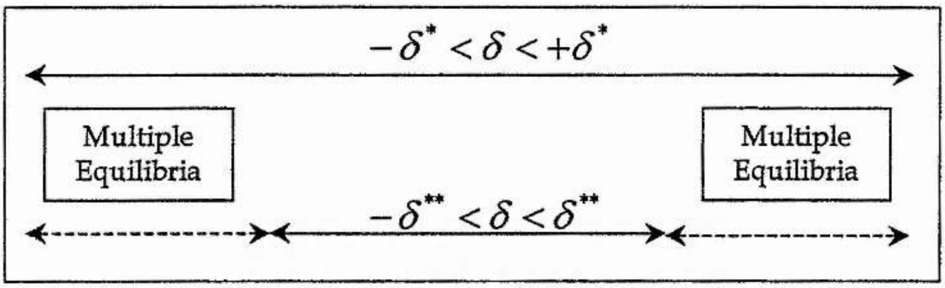

Figure 3: multiple equilibria in nominal price adjustment

⟷ denotes the range of nominal shocks for which non-adjustment is an equilibrium choice for a single firm.

⇠⇢ denotes the range of nominal shocks for which adjustment is an equilibrium choice for a single firm.

Appendix to Chapter 2

1. Derivation of (15a)

In order to derive the optimal nominal pricing rule in (15a) both the market demand and the cost function faced by firm i must be specified[74]. The market demand is defined by

(1Ap) $$d_i = \left(\frac{P}{P_i}\right)^{\alpha_0}\left(\frac{N}{P}\right)^{\alpha_1} \qquad \alpha_0 > 1, \text{ and } 0 < \alpha_1 < \alpha_0,$$

where:

P_i is the nominal price quoted by firm i;

P is the aggregate price level;

N is the nominal scale variable.

Assuming that labour, l, is the only input, firm i's production function is given by

$$y_i = l^{1/\gamma} \qquad \gamma > 1,$$

where y_i is firm i's level of output.

Letting W be the nominal wage cost, firm i's cost function reads

(2Ap) $$C_i = W \cdot (y_i)^{\gamma}.$$

Under the assumption of fully flexible input nominal prices, $W \approx N$.

Firm i's objective is to quote P_i as to maximise its profit, i.e.,

(3Ap) $$\max_{P_i} \Pi_i = P_i \cdot d_i - C_i \equiv P_i^{(1-\alpha_0)}\, P^{(\alpha_0-\alpha_1)} N^{\alpha_1} - P_i^{-\gamma\alpha_0}\, P^{\gamma(\alpha_0-\alpha_1)} N^{1+\gamma\alpha_1}.$$

Solving the profit maximisation problem in (3Ap) yields:

$$P_i^{1+\alpha_0(\gamma-1)} = \frac{\alpha_0}{\alpha_0-1}\gamma\; P^{(\alpha_0-\alpha_1)(\gamma-1)} N^{1+\alpha_1(\gamma-1)}.$$

Consequently,

(4Ap) $$P_{i,MAX} = k^{1/b} P^{a/b} N^{c/b},$$

where:

[74] More details are in Andersen (1994), p. 41-3.

$k=\frac{\alpha_0}{\alpha_0-1}\gamma$;

$b=1+\alpha_0(\gamma-1)$;

$a=(\alpha_0-\alpha_1)(\gamma-1)$;

$c=1+\alpha_1(\gamma-1)$.

Since c/b is equal to $1-a/b$, (4Ap) can be written as

(5Ap) $$P_{i,MAX}=P^{\varpi}N^{1-\varpi}$$ QED,

where a/b has been replaced by ϖ and k has been normalised to unity, for simplicity.

By expressing the price formula (5Ap) in log terms, it is straightforward to see that:

$$\varpi=\frac{\partial \ln P_i}{\partial \ln P}.$$

That is why ϖ can be regarded as a measure of the degree of strategic complementarity in price decisions.

2. Derivation of (16a)

The second-order Taylor approximation of firm i's profit function $\Pi_i(P_i,N_1,P)$ around the point ${}_1P_{i,MAX}$ reads:

$$\Pi_i(P_i,N_1,P)\cong\Pi_i({}_1P_{i,MAX},N_1,P)+\frac{\partial\Pi_i({}_1P_{i,MAX},N_1,P)}{\partial P_i}(P_i-{}_1P_{i,MAX})+\frac{\partial^2\Pi_i(\cdot)}{\partial P_i^2}\frac{(P_i-{}_1P_{i,MAX})^2}{2}.$$

For the first order condition of profit maximisation problem $\frac{\partial\Pi_i(\cdot)}{\partial P_i}$ is equal to zero.

Now, setting P_i equal to ${}_0P_{i,MAX}$ the second order Taylor approximation for the second term of (16) yields:

$$\Pi_i({}_0P_{i,MAX},N_1,P)\cong\Pi_i({}_1P_{i,MAX},N_1,P)+\frac{\partial^2\Pi_i(\cdot)}{\partial P_i^2}\frac{({}_0P_{i,MAX}-{}_1P_{i,MAX})^2}{2}.$$

Substituting it into (16) yields (16a), QED.

3. Derivation of (18)

Consider the LHS expression in (17a). Substituting 1 and $1+\delta$ for P_1 and N_1, respectively, yields

$$-\frac{1}{2}\frac{\partial^2\Pi_i}{\partial P_i^2}\left[1-(1+\delta)^{1-\omega}\right]^2$$

Using the first-order Taylor approximation $(1+x)^m \cong 1+mx$, the above expression becomes

$$-\frac{1}{2}\frac{\partial^2\Pi_i}{\partial P_i^2}\left[-\delta(1-\omega)\right]^2, \qquad \text{QED.}$$

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CHAPTER 3:

The microeconomics of menu costs

The microeconomics of menu costs

Theoretical studies on costly price adjustments date back to the early 1970s. Most of them focus either on monopoly or on monopolistic competition. Attempts to analyse menu costs within a strategically interactive setting are rare indeed and typically consider real rather than nominal shocks. The first part of the chapter surveys some of the relevant microeconomic studies on menu costs. Section 1 outlines Barro (1972) and Sheshinski and Weiss (1977). It will be shown that the optimal pricing policy for a monopolist faced with costly price adjustments and a continuously increasing rate of inflation takes the form of an (S,s) rule. In Section (2), an overview of recent game-theoretic frameworks with menu costs is given. It will be argued that these models fail to capture the theoretical essence of menu costs. The last part of the chapter deals with the issue of the empirical relevance of costly price adjustments. What do menu costs look like? Are they simply administrative costs related to the technology used to quote monetary prices; or must they be given a broader interpretation?

1. Theoretical studies: the forerunners

Menu costs are often associated with New Keynesian economics. Nonetheless, theoretical studies on costly price adjustments can be traced back at least to the early 1970s, when J.R. Barro issued his seminal notes on monopolistic price adjustment[1]. The purpose of the paper was to cast light on price response to out-of-equilibrium situations in markets where sellers rather than the fictitious Walrasian auctioneer were expected to set prices. To this end, Barro considered a monopoly price-setter faced with a stochastic demand schedule and examined the price responsiveness to unexpected demand variations[2]. In so far as price adjustments are costless, it is optimal for the monopolist to make his/her price vary promptly in such a way that the profit maximisation condition, i.e., marginal revenue equal to marginal cost, is

[1] See Barro (1972). There is an earlier literature on price adjustment and, consequently, on the validity of the law of supply and demand across different market structures. But costs of changing prices were ignored. See, among others, Arrow (1959) and Gordon and Hynes (1970).

always met. The "Law of Supply and Demand" according to which price movements are inversely related to the excess of supply, therefore, holds continuously. So

$$\frac{dp}{dt} = f(S - D) \qquad \text{with } f' < 0 \text{ and } f(0) = 0,$$

where t denotes time and $(S - D)$ excess of supply.

But, as soon as price changes are associated with some (lump-sum) costs, then a trade-off arises between adjustment and non-adjustment. Let z and $\Delta\pi$ denote, respectively, the cost of changing prices and the cost of keeping the price fixed at a suboptimal level (i.e., where marginal revenue differs from marginal cost). The individual price-setter will choose to adjust his/her price only when $\Delta\pi$ turns out to be larger than z. As a result, the monopolistic price adjustment rule comes to take a discrete rather than a continuous form. Price amendments do not occur at each out-of-equilibrium situation, but only occasionally. The "Law of Supply and Demand" still holds: prices do not go up when supply exceeds demand. Nonetheless, the above differential equation is no longer suitable for describing the optimal price adjustment rule arising when some sort of price adjustment cost exists[3].

1.2 Menu costs and the effects of inflation

Barro's (1972) theoretical study paved the way for subsequent and more particular analyses. Specifically, E. Sheshinski and Y. Weiss, starting from the consideration that price variations may be called for by either nominal or real changes in the state of the nature[4], focused their studies on how inflation, along with menu costs, can affect the monopolistic price adjustment policy. In their 1977 paper a constant and certain rate of inflation was considered; whereas in the 1983 article they extended the analysis to the case of stochastic inflation. In line with Barro's (1972) conclusions, Sheshinski and Weiss found that costly price adjustments can induce a monopoly firm to change its nominal price «occasionally rather than continuously». And this even when future inflation is fully anticipated.

[2] The nature of the disturbances is left unspecified.

[3] See Barro (1972), p. 24.

Key features of the Sheshinsky and Weiss (1977) model are:

i) the state of nature continuously changes over time because of a constant rate of inflation;

ii) movements in the real side of the economy, if any, are nominally based. Thus, real variables are *per se* time invariant (unless money turns out to be non-neutral);

iii) the inflationary process is non-stochastic. The monopolistic price-setter predicts exactly the rate of inflation at any time and no uncertainty affects the economy;

iv) adjustments of nominal price are costly[5]. In particular, the cost of changing price is supposed to be lump-sum.

Within this dynamic model a profit maximising firm when choosing its optimal price policy must take into account that inflation continuously erodes the real price underlying its quoted nominal price, and that every nominal price adjustment implies a cost.

Some notation[6]:

P_t: nominal price charged by the monopoly firm at time *t*.

G_t: rate of inflation at time *t*.

r_t: real interest rate at time t.

z_t: real lump-sum cost of adjusting price at time *t*.

As the rate of inflation, the real interest rate, and the lump-sum menu cost are supposed to be constant over time, the *t* subscript is dropped out henceforth.

$\overline{P_t} \equiv e^{Gt}$: aggregate price level at time *t*; ($\overline{P_0}$ is normalised to 1).

$p_t \equiv P_t / \overline{P_t}$: underlying real price at time *t*.

$\pi(p_t)$: real profit[7] at time *t*.

v_0: present discounted value of real profits at time 0.

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[4] Nominal changes are commonly associated with variations in money stock, and real changes with technology improvements.

[5] As in most menu cost macromodels, nominal input prices (especially nominal wages) are supposed to be fully flexible. So, real marginal costs are constant over time. Furthermore, output is implicitly assumed to be always equal to sales, whatever p_t.

[6] Capital letters denote nominal magnitudes.

[7] The profit function is supposed to be differentiable and strictly quasi-concave so as to ensure the existence of a unique maximum.

Now, if $[t_\tau, t_{\tau+1}]$ is any interval over which the nominal price is left unchanged, the flow of net real profit during this time period discounted to time 0 is given by:

(1) $$\int_{t_\tau}^{t_{\tau+1}} \pi\left(P_\tau \cdot e^{-Gt}\right) \cdot e^{rt}\, dt - z \cdot e^{-rt_{\tau+1}},$$

where:

P_τ denotes the fixed nominal price over the $[t_\tau, t_{\tau+1}]$ interval;

$ze^{-rt_{\tau+1}}$ is the cost of adjusting price incurred at time $t_{\tau+1}$ discounted at time 0.

The present discounted value of real profits at time 0 is given by the sum of expressions like (1), each one referring to the interval between two immediately subsequent nominal price adjustments:

(2)[8] $$v_0 = \sum_{\tau=0}^{\infty} \left[\int_{t_\tau}^{t_{\tau+1}} \pi\left(P_\tau \cdot e^{-Gt}\right) \cdot e^{-rt}\, dt - z \cdot e^{-rt_{\tau+1}} \right]$$

Notice that in (2) the summation operator indicates that the nominal price is changed discretely. Whereas the integral operator denotes that the underlying real price varies continuously over the interval $[t_\tau, t_{\tau+1}]$, and so does the profit.

The decision problem faced by the firm consists of determining the optimal price policy, namely the sequences of nominal prices, $\{P_\tau\}$, and of points in time, $\{t_\tau\}$, $\tau = 1,2,...,$ that maximise v_0.

Let us focus for a moment on the simple case of the finite time horizon: $0 \le \tau \le 2$.

v_0 reads

$$\int_{t_0}^{t_1} \pi\left(P_0 \cdot e^{-Gt}\right) \cdot e^{-rt}\, dt - ze^{-rt_1} + \int_{t_1}^{t_2} \pi\left(P_1 \cdot e^{-Gt}\right) \cdot e^{-rt}\, dt - ze^{-rt_2};$$

firms choice variables are t_1 and P_1. The first order conditions for the maximisation of v_0 yield:

(3a) $$\frac{\partial v_0}{\partial t_1} = 0 \Rightarrow \left[\pi\left(P_0 \cdot e^{-Gt_1}\right) + zr - \pi\left(P_1 \cdot e^{-Gt_1}\right)\right] \cdot e^{-rt_1} = 0,$$

[8] The initial nominal price, P_0, is assumed to be given. Moreover, t_0 is set equal to 0. v_0 is supposed to be such that an interior maximum does exist.

(3b) $\frac{\partial v_0}{\partial P_1} = 0 \Rightarrow \int_{t_1}^{t_2} \frac{\partial \pi}{\partial P_1} \cdot e^{-(r+G)t} dt = 0$.

From (3a) and (3b) it is straightforward to derive the general first order conditions for the maximisation of (2). These are:

(4a) $\frac{\partial v_0}{\partial t_t} = \left[-\pi\left(P_\tau e^{-Gt_\tau}\right) + \pi\left(P_{\tau-1} e^{-Gt_\tau}\right) + zr\right] \cdot e^{-rt_\tau} = 0 \qquad \tau = 1,2,\ldots,$

(4b) $\frac{\partial v_0}{\partial P_\tau} = \int_{t_\tau}^{t_{\tau+1}} \frac{\partial \pi}{\partial P_\tau} \cdot e^{-(r+G)t} dt = 0 \qquad \tau = 1,2,\ldots.$

The optimal nominal pricing policy for the firm is given by solving the above set of equations for P_τ and t_τ. As the relevant real variables are time-independent, this policy turns out to be periodic[9], i.e., the firm finds it optimal to adjust its nominal price at fixed intervals, $t_{\tau+1} - t_\tau = \varepsilon$ (ε positive constant), according to the rule $P_{\tau+1} = P_\tau \cdot e^{G\varepsilon}$, $\forall \tau = 1,2,\ldots$.

Such policy implies that the underlying real price in each fixed-nominal-price period, ε, is continuously eroded by the constant rate of inflation, *G*. More precisely, at the beginning of ε, when the nominal adjustment takes place, the real price turns out to be equal to an upper bound value, $s_U \equiv P_\tau \cdot e^{-Gt_\tau}$. Over ε the real price continuously slides towards a lower bound, $s_L \equiv P_\tau \cdot e^{-Gt_{\tau+1}} \equiv s_U \cdot e^{-G\varepsilon}$, which is reached at the end of the period. At this point, a new price adjustment occurs and the real price bounces back to s_U. The symbols (s_U, s_L) have been used instead of the more common (*S,s*) to avoid confusion[10].

Conditions (4a) and (4b) can be re-written as follows:

(5a)[11] $\pi(s_L) + zr - \pi(s_U) = 0$,

[9] For the formal proof see Sheshinski and Weiss (1977). For an intuitive explanation see also Andersen (1994), p. 81.

[10] I recall that in my description of Sheshinski and Weiss (1977) capital letters denote nominal variables. It may be interesting to note that the *(S,s)*-type policy emerged originally from the investigation into the inventory holding problem. For some references see both Barro (1972) and Sheshinski and Weiss (1977) and (1983).

[11] This condition has been derived by applying the transformation $p_t = P_t \cdot e^{-Gt}$ to (4a).

(5b) $$\int_{t_\tau}^{t_\tau+\varepsilon} \frac{\partial \pi}{\partial P_\tau} \cdot e^{-(G+r)t} dt = 0 .$$

The former equation says that the optimal lower and upper bounds, s_L and s_U, respectively, are chosen in such a way that the gain from postponing the adjustment, i.e., the interest saved on the adjustment cost, zr, equals the gain from adjusting the nominal price, $\pi(s_U) - \pi(s_L)$. In passing, the price policy is not symmetric around the time-invariant optimal real price, p_*, notably, $\pi(s_U)$ is larger than $\pi(s_L)$; see Figure 1. The latter equation says that ε is chosen so that the average of present value marginal profits over ε is equal to zero.

FIGURE 1 at the end of the chapter.

It is important to notice that marginal costs are not equal to marginal revenues at s_U. Which means that the optimal real price, p_*, lies within the open interval $]s_L, s_U[$. Thus, «the firm operates initially with negative marginal profits and with positive marginal profits towards the end of each period»[12]. This can be seen from (5b). If s_U were equal to p_*, then (5b) would never be met. Specifically, the average present value marginal profits would be always positive. For (5b) to be met, some marginal profits over ε must be negative, which implies that s_U must be strictly larger than p_*.

As mentioned, Sheshisnki and Weiss (1983) extended the analysis by allowing for stochastic inflation. Uncertainty was introduced into the model through the assumption that the economy swings randomly between two deterministic states of nature; one with zero inflation, the other with a positive and constant rate of inflation, *G*, just like in Sheshinski and Weiss (1977). Let the former state of nature be denoted by 0 and the latter by 1. Let also $T_0(t)$ and $T_1(t)$ be the total time spent in state 0 and 1, respectively, during the interval $[0,t]$. The aggregate price level, $\overline{P_t}$,

[12] See Sheshinski and Weiss (1977), p. 290.

continuously increases only in state 1. In particular, over $[0,t]$ it evolves according to the rule $\overline{P_t} = e^{GT_1(t)}$, being $\overline{P_0} = 1$.

The key 1977 result was confirmed. The (s_U, s_L) pricing rule still holds. The nominal price adjustment takes place when the underlying real price has reached a bottom value, s_L. And the nominal change is such that the underlying real price jumps back to an upper limit, s_U. But, as the inflationary process is now supposed to be stochastic, the fixed-nominal-price period, ε, comes to be random. In passing, s_U and s_L do not change over time simply because the non-zero rate of inflation, G, is supposed to be constant. As soon as the assumption is relaxed, the (s_L, s_U) values turn out to vary over time[13].

Both in their (1977) and in the (1983) analysis Sheshinski and Weiss investigated also how the rate of inflation, G, and the size of menu costs, zr, can affect the difference between the upper and the lower bounds, $(s_U - s_L)$, as well as the frequency of price adjustments (i.e., the length of ε). While the effects of changes in the rate of inflation appear to be dependent on the type of model (certainty or uncertainty)[14], no doubt that an increase in the size of menu costs leads to a less frequent price change and, accordingly, to larger price adjustments, when they take place.

2. Costly price adjustments and oligopoly

Dealing with costly price adjustments requires a departure from the perfect competition framework, in which price decisions are delegated to an impersonal auctioneer. Such departure can take on as many shapes as there are alternative types of imperfectly competitive markets. Nonetheless, the imperfection on which the prevailing menu cost macromodels[15] are based has mainly the form either of monopoly or of monopolistic competition, where strategic interaction is absent. To the best of my knowledge, only J.J. Rotemberg and M. Woodford set up a (general

[13] See Sheshinski and Weiss (1983), footnote 2.

[14] See Sheshinski and Weiss (1983), p. 514.

[15] For references on menu cost macromodels see, among others, Mankiw and Romer (1991) and Andersen (1994).

equilibrium) macromodel with oligopolistic firms and costly price adjustments[16]. Their analysis was empirically-oriented and little attention was devoted to theoretical implications. The authors' purpose was, in fact, to compare the predictive power of their model with an analogous perfectly competitive framework. Hence, they computed the two models' forecasts of the economy's responses to exogenous aggregate demand shocks (in the form of changes in the U.S. Government military spending) and checked which of the two predicted series better matched the empirical responses derived from U.S. data. In passing, the findings were in favour of their oligopolistic model.

The search for oligopoly models with costly price adjustments will appear to be slightly more fruitful, if one turns the attention to the microeconomic literature. In particular, game-theoretic frameworks aimed to investigate into the implications of menu costs for strategically interactive price-setters are set up in Bernahrdt (1993), Slade (1996a) and Hansen *et al.* (1996)[17]. Also Rotemberg and Saloner 1987 model, to be sure, considers oligopoly price-setters faced with menu costs. Nonetheless, the analysis is barely concerned to shed light on the strategic implications of costly price adjustments. The authors' intention is, indeed, to provide a theoretical justification for the well established observation[18] that «monopolists generally change their prices less frequently than oligopolists». To this end, Rotemberg and Saloner focus on menu costs as the reason why rational price-setters may opt for nominal sticky prices. Under the assumption of costly price adjustments they analytically derive «the relative incentives of monopolists and duopolists to adjust their prices when underlying cost and demand conditions change or when inflation erodes existing prices». A comparison of such incentives reveals that the cost of keeping prices fixed

[16] See Rotemberg and Woodford (1992).

[17] Notice that there are more game-theoretic models where prices are sticky. I refer, in particular, to Fershtman and Kamien (1987) and (1990), Tsutsui and Mino (1990). Yet, price rigidity is assumed rather than derived. In Fershtman and Kamien 1987 model, for example, (real) price rigidity arises because the current desirability for each duopoly firm's homogeneous output is supposed to be «an exponentially weighted function of accumulated past consumption». It leads to rigidity in the current price. Notably, «the current price of the good does not decline by as much to accommodate any given level of current consumption as it would be if its desirability were a function solely of present consumption»; see Fershtman and Kamien (1987), p. 1151.

is higher for each tight duopoly price-setter than it is for a monopolist, facing the same configuration of demand. Hence, the relative rigidity of monopoly pricing. In Rotemberg and Saloner's words, «circumstances that lead a monopolist to change its prices would always encourage duopolists to do so as well, while the reverse is not true»[19].

Reverting to the three models mentioned above, namely Bernhardt (1993), Slade (1996a) and Hansen *et al.* (1996), they share a common feature: they neglect to distinguish between nominal and real magnitudes. Specifically, all variables are expressed in *real* terms and no emphasis is placed on whether the source of the disturbances is nominal or real. In Bernhardt (1993) the economy is assumed to be affected by «a shock to production costs which is common to all firms». Letting c_0 denote the initial value of the real marginal cost of production, which is identical for all firms, the *ex-post* real marginal cost is given by

$$c_1 = (1 + \mu + \delta_1)c_0,$$

where μ is a predictable linear trend in marginal cost evolution over time, and δ_1 represents the white noise shock to costs.

As for the source of δ_1, according to Bernhardt, «[o]ne could interpret it as technology shock, or assume that it is nominally based» [20]. Notice, however, that in so far as the shock is assumed to be nominally based, it is necessary to specify the reasons of its *real* effects (i.e., the change in the real marginal cost). In particular, it is necessary to specify what prevents nominal magnitudes from promptly and fully adjusting in response to the nominal shock. In Bernhardt (1993), to be sure, these reasons can be neither the existence of menu costs, nor the price-setters' reaction to the presumed nominal shock. The real marginal cost's variation, in fact, occurs prior

[18] Rotemberg and Saloner (1987), pp. 917-8, provides a list of empirical analyses, dating back to the Stigler's 1947 study, where the relative rigidity of monopoly and oligopoly prices is compared.
[19] See Rotemberg and Saloner (1987), p. 925.
[20] See Bernhardt (1993), p. 529.

to any price-setters' decisions[21]. It turns out that the source of the disturbance must be real[22].

We shall come to the same conclusion, if we look at Hansen *et al.* (1996). Here, the shock generates a shift in the demand function faced by each strategically interactive firm. Let producer *i*'s demand function be

$$q_i = a - bp_i + cp_j \quad \text{with } i = 1,2 \neq j,$$

where p_i and p_j are the real prices of goods produced by firm *i* and *j*, respectively. Following a «completely unanticipated shock», the demand's intercept, a, varies by Δa. Just like in Bernhardt (1993), in Hansen *et al.* (1996) as well the shock has real effects irrespective of how price-setters respond to it. As a result, its source cannot be nominal.

Finally, Slade (1996a) considers a zero-inflation economy (monetary variables are time invariant) and no distinction between real and nominal prices is made[23]. Also in this case the source of the (generic) shock turns out to be real.

In the light of the foregoing, the allegation that neither Bernhardt (1993), nor Hansen *at al.* (1996), nor Slade (1996a) capture the essence of menu costs does not seem inappropriate. To make my point clear, recall that the costs of adjusting nominal prices are theoretically relevant because they allow of a reconciliation between rationality and nominal price rigidity. Small menu costs can induce profit-maximising price-setters not to adjust their monetary prices, despite the occurrence of a *nominal* shock. The resulting nominal price rigidity[24] causes the classical dichotomy to break down. Thus, monetary disturbances have real effects only in case of (some degree of) nominal rigidities. A completely different story holds for real disturbances. They always have real effects. No matter whether nominal prices are rigid or not and, consequently, no matter whether nominal barriers (such as menu

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21 Price-setters' decision problem as to whether adjust or not their prices is indeed triggered by the unexpected change in the real marginal cost.

22 The only way the cost shock in Bernhardt (1993) can be regarded as nominally based is to assume that there is some degree of nominal rigidity within other markets, different from the one under study.

23 It is a zero-inflation economy. See Slade (1996a), p. 3.

24 Monetary prices are said to be rigid if they do not promptly and fully adjust to monetary disturbances.

costs) exist or not. It turns out that the existence of costly nominal price adjustments is far more crucial within a setting where monetary variables are clearly identified and where nominal rather than real disturbances are taken into account. I shall return to this point in the next chapter. Therein, the response of strategically interactive price-setters faced with menu costs to a shock, whose source is definitely nominal, will be analysed.

3. Empirical studies

Since the macroeconomic debate on nominal rigidity has turned its attention to the goods market, there has been a revival of empirical investigations into price behaviour[25]. Over the last decade and more, surveys have been carried out in order to determine whether prices are sticky; and if so, what induces firms to keep prices unchanged. The results are twofold. On the one hand, they strongly support the idea of price rigidity. Prices of many different goods are found to remain unchanged for one year or even more[26]. Some caveats must however be added. First of all, unchanged prices do not necessarily imply price rigidity. If economy is not affected by any disturbance, prices will be certainly fixed. Secondly, it is hard to detect whether recorded price movements are due to nominal or real shocks. So, the observed rigidity may refer to real as well as to nominal prices. Finally, the results depend upon the type of goods considered. For example, if the commodity can be easily differentiated, firms may react to changes in the state of nature by putting on the market along with the "old" product a "new" one, slightly different from the former[27]. In doing so, firms can leave the price of the old product unchanged, whereas the price of the new commodity is set optimally[28]. Under these

[25] Empirical analyses on price behaviour have a long history, dating back to the late 1920s. See Carlton (1989) for a short overview and references therein. See also Gordon (1990).
[26] Among others see Rotemberg (1982b), Carlton (1986), Cecchetti (1986), Roberts (1992), Blinder (1994), Kashyap (1995), Hall *et al.* (1996). See also Neumark and Sharpe (1992), where price rigidity is examined within banking industry.
[27] For instance, because of a new colour or a new packaging.
[28] This strategy was suggested to me by some Italian businessmen in the textile industry.

circumstances, a price investigation performed into the "old" commodity will suggest a higher degree of rigidity than it is in reality[29].

As regards the source of the rigidity, on the other hand, microeconomic evidence is still puzzling; in the sense that price behaviour emerging from the empirical investigations does not follow any simple pattern. Accordingly, the type and the concrete features of the barriers which lead to rigid prices are still shrouded in mystery. Are costly price adjustments a suitable type of nominal friction for fitting the facts? And if yes, what they look like? The former question can be possibly better answered by those who set prices. This was Blinder's suggestion who carried out an interview study among a sample of American businessmen in order to test different theories of price rigidity[30]. Though not brilliantly, costly price adjustments passed the exam[31]. They got an average score of 1.89 out of four[32]. But as for their features, namely whether they are constant or variable, consensus is far from being reached. Such lack of unanimity is mainly due to the fact that the empirical evidence of menu costs is elicited indirectly[33]. Infrequent and relatively large price changes are taken as a clue of lump-sum menu costs. While the existence of variable menu costs is commonly inferred from frequent and relatively small price changes. Unfortunately, the size and frequency of price adjustments observed in many studies vary

[29] On the idiosyncratic results of empirical studies into price behaviour see also Gordon (1990), in particular pp. 1118-23.

[30] Twelve theories of price rigidity were tested. It must be said, however, that many of those refer to real price rigidity.
Blinder's empirical study departs from the traditional research strategies largely adopted by economists and based on econometrics. For a description of the research strategy and criticism see Blinder (1991) and comments therein. An analogous research was carried out also across British companies by the Bank of England, see Hall *et al.* (1996).

[31] See Blinder (1994). Different results were derived from the survey in UK, where menu costs, explicitly defined as physical costs of changing prices, did not receive much attention from the interviewees. Such findings, however, do not necessarily hold for a broader interpretation of menu costs. See Hall *et al.* (1996).

[32] The highest average score was 2.77, for the coordination failure theory.

[33] A direct scrutiny of costly price adjustments is difficult. A recent attempt to measure explicitly the magnitude of menu costs has however been made in Levy *et al.* (1997), where microeconomic data referred to five large U.S. supermarket chains are analysed. The findings display that (at least) in the U.S. retail supermarket industry: (i) fixed menu costs exist; (ii) they are non-trivial (on average 0.70 percent of total revenues); (iii) they do represent a barrier to price changes. A direct empirical investigation into the costs of changing price is carried out also by M. E. Slade. She estimated the type and magnitude of menu costs econometrically. The results support the idea of fixed menu costs; see Slade (1996b).

enormously across goods and, what is more, across time for the same item. That is why empirical evidence is of little help to definitely decide in favour either of constant costs or of variable costs of changing nominal prices[34].

The foregoing reveals the difficulty providing a concrete identification of the costs a firm is expected to incur in changing its nominal prices[35]. It might be true that the solution of such identification problem does not have to worry (macro)theorists too much. As argued by Ball and Mankiw, «... a literal account of menu costs is not necessary for studying most issues in macroeconomics». Menu costs are just an allegory, a parable, «a convenient formalization that captures the fact that prices are not adjusted continuously». They represent an "as if" theoretical device; just like the fictitious Walrasian auctioneer[36]. Yet any endeavour to peg the allegory to some concrete, plausible example is still widely thought of as being worthwhile[37].

4. What are menu costs?

The puzzle arising from the empirical analysis on price rigidity leaves open the question whether menu costs are fixed or variable. A possible way to solve the dilemma is to try to figure out what fixed and variable costs, in turn, can look like in the real world economy. What follows is a critical overview of alternative suggestions made in order to «go beyond the parable». Though none of them proves to be completely convincing, lump-sum menu costs emerge as the ones that are far more consistent with traditional microeconomics[38].

Fixed, or administrative costs of changing nominal prices are, by definition, independent from the size of price adjustments. In the literature it is common to associate them with the physical costs of printing new catalogues or new price lists.

[34] On indirect empirical support for fixed menu costs see, among others, Carlton (1986), Cecchetti (1986), Carlson (1992), Blinder (1994), Kashyap (1995). As for variable menu costs, see Rotemberg (1982b), Roberts (1992), Konieczny (1993), and Kashyap (1995).

[35] See Blinder (1991) and Kashyap (1995), p. 262.

[36] «It is no more appropriate to insist on an exact identification of menu costs than it is to demand the social security number of the Walrasian auctioneer». See Ball and Mankiw (1994), pp. 142-3.

[37] Blinder (1994), Kashyap (1995), Slade (1996b), and Levy *et al.* (1997) remark «the importance of assessing the empirical relevance of menu costs». Ball and Mankiw themselves recognise that «it is still interesting to go beyond the parable to better understand the foundations of nominal frictions». See Ball and Mankiw (1994), p. 143. See also Romer (1993).

More general, with the costs of informing salesmen, dealers and customers about the new nominal prices. Nonetheless, this sort of costs has received little empirical support. Kashyap (1995), for example, reveals that catalogues are issued much more frequently than prices are amended. Notably, some of the biggest United States mail-order companies issue a number of new catalogues per year, whereas the price of their core business items remains unchanged for periods on average longer than twelve months. Were the physical costs of printing new catalogues the main obstacle to price flexibility, one would expect the issue of new catalogues to be highly related to the occurrence of price changes. In line with these results are those of Blinder (1994) and Levy *et al.* (1997). The latter, in particular, show that the costs of printing new price tags account for less than six percent of the total costs incurred by U.S. retail supermarkets when prices are changed[39].

It seems more plausible to identify lump-sum menu costs with "managerial costs". The process of gathering the relevant information as well as taking and implementing price decisions require time and attention[40]. Accordingly, frequent price revisions are costly in terms of managers' hours spent on determining whether the profit maximisation conditions are continuously met. As pointed out in Levy *et al.*'s quantitative 1997 analysis, the more decentralised price change decisions are, the larger should be the managerial costs[41]. To take an example of a decentralisation of the price change process, consider a supermarket chain where store-level managers rather than a corporate management team are in charge of making price change decisions.

However realistic the identification of menu costs with informational costs and, in general, with the costs of managers' time, I am afraid that it may turn out to be less credible in the coming years. The massive computerisation and the introduction of new technology along with the easy access to on-line information, are likely to make

[38] Notice that the bulk of theoretical models assumes fixed rather than variable menu costs.

[39] In Levy *et al.* (1997) the (fixed) costs of changing nominal prices are made up of different components.

[40] See, Ball and Mankiw (1994) and Levy *et al.* (1997). Indirect empirical evidence of menu costs as «informational costs» has been found also by Hall *et al.* (1996).

[41] See Levy *et al.* (1997), p. 808-9.

automated pricing decisions more and more popular within the near future. With the consequence of making such "managerial costs" less and less relevant to nominal price rigidity[42].

Price adjustment costs have been also regarded as implicit costs arising from unfavourable market reactions to nominal price movements, no matter whether upwards or downwards[43]. The argument underlying this view, which is commonly used for describing variable menu costs[44], is that consumers dislike frequent price variations. Unfortunately, the above identification, if appealing at first sight, proves to be theoretically fragile. Let us see why. Buyers' aversion to price movements is commonly justified by information costs. The search for novel and up-dated information is costly. In so far as buyers behave rationally, a new information search has to be triggered only by real price movements[45]. From a theoretical point of view, there is no reason for price-setters to fear a bad reaction of the demand-side, when nominal prices are adjusted in response to nominal shocks. The same argument holds also when implicit menu costs are explained by means of the theory of judging quality by price[46]. It is the behaviour of *relative* (i.e., real) prices that *rational* consumers look at in order to evaluate the quality of a commodity[47].

The fatal flaw intrinsic to the justifications mentioned above is that sources of real price rigidity are used to describe the implicit costs of nominal price adjustments. To the extent one aspires to interpret the parable of menu costs as buyers' dislike of price movements, he/she needs to account for consumers' attention to nominal magnitudes. To this end, the following observation seems promising[48]. In the real

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[42] See also Kishyap (1995), p. 269.

[43] Costly price adjustments are symmetric, which is independent from the sign of price movements.

[44] See Rotemberg (1982a) and Konieczny (1993), where buyers are said to dislike *large* price changes.

[45] According to the canonical economic theory, rational agents care only about real magnitudes. In a non-auction market, where (fairly) homogeneous goods are traded in different places (e.g., different retailers), it takes time to search for the "best" real price. So, information costs may represent a barrier to *real* price flexibility. The role of information costs within the economic system was first studied by Stigler (1961).

[46] The idea of prices as a quality index dates back to the work of Scitovs(z)ky (1943-45). In late 1980s this topic experienced a revival mainly due to the fortune of the theory of imperfect and asymmetric information. See Blinder (1994), p. 144-7 and references therein.

[47] Notice, however, that empirical evidence does not support the theory. See Blinder (1994) and Hall *et al.* (1996).

[48] See Romer (1993).

world economy prices are expressed in nominal rather than in real terms. If some sort of administrative costs prevent them from being continually adjusted, individuals may be led to attach significance to money prices. Using D. Romer's words, «an unchanged nominal price [...] may come to be viewed as the norm». The result is that sources that, by themselves, do not constitute barriers to nominal price adjustments (e.g., information costs) end up to be partly associated with changes in nominal prices. «Nominal rigidity may therefore be both stronger and more complicated than it would be if [fixed] menu costs alone were the only frictions»[49].

An elegant account of why nominal prices matter can be derived also by combining the Akerlof and Yellen's idea of "near rationality" with the so called price point theory. As everyone can experience in his/her every day life prices are usually quoted as if some special thresholds exist. Kashyap (1995), for example, pointed out that dollar prices are much more likely to end between 40 to 51 cents or between 75 to 00 cents, than between 01 to 40 and 51 to 74 cents[50]. This fact may be captured by assuming that consumers are near rational. Here, by near rationality I mean that consumers discriminate between different money prices (in absolute terms), even though they do not suffer from monetary illusion. Put differently, they «use rules of thumb when searching for items and comparing prices»[51]. As a result, nominal prices within these thresholds tend to be less sensitive to nominal disturbances.

Despite the empirical accreditation of the near rationality hypothesis, the attempt to provide a conceivable justification for implicit menu costs[52] risks being accused of internal inconsistency. Recall that costly price adjustments are intended for reconciling the "full rationality" postulate with nominal rigidity and money non-neutrality. Arguing that this type of nominal friction emerges from a near rational behaviour it can be seen as a contradiction to the declared intention. More in general, if menu costs proved to be the allegory of rules-of-thumb behaviour, the New

[49] See Romer (1993), p. 18.

[50] For empirical evidence of price point theory see also Blinder (1994) and references in Kashyap (1995).

[51] See Kashyap (1995), p. 266.

[52] Notice that price point theory seems suitable for an explanation of upwards nominal rigidity, only. The corresponding menu costs, therefore, turn out to be asymmetric.

Keynesian research program would turn into a partial failure and the label "New" should be dropped.

To sum up, the transposition of the theoretical device of menu cost into concrete and plausible forms is far from straightforward. Especially as regards variable menu costs. The analogy of costly price adjustments with the black holes in astrophysics seems therefore appropriate: they must exist, but none as yet can exactly say what they look like.

FIGURE 1

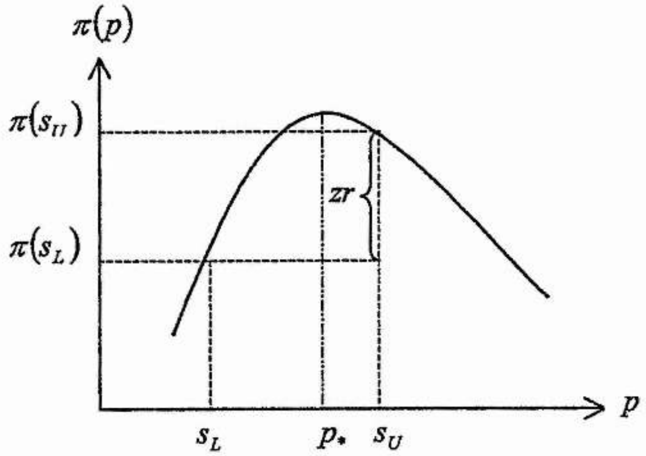

Figure 1: asymmetry in the (s_U, s_L) pricing rule

p_* : time-invariant optimal real price.

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CHAPTER 4:

Menu costs and strategic interaction

Chapter 4: Menu costs and strategic interaction

The prevailing literature on the costs of adjusting nominal prices focuses on the behaviour either of monopolists or of monopolistic competitors. Strategic interaction between price-setters is therefore ignored. The rare attempts to analyse menu costs within a game-theoretic setting appear to have underestimated the theoretical relevance of menu costs. This chapter presents a theoretical study that can contribute to fill the gap. Section 1 briefly introduces the issue. In Section 2, a Bertrand duopoly model with menu costs is set up in order to derive the duopolists' best response to a nominal shock. To start with, a generic demand structure for each duopolist is considered (Section 2.1). It will be shown that firm-specific nominal price rigidity can occur even when menu costs are set equal to zero. A specific functional form is chosen in Section 2.2. The main findings are expounded in Section 3 where the cases of zero and of strictly positive menu costs are in turn outlined (Section 3.1 and 3.2, respectively). A duopoly nominal price adjustment rule will be derived. This turns out to be asymmetric, i.e., contingent to the sign of the nominal shock. Situations of multiple equilibria, both symmetric and asymmetric, can also arise.

1. Introduction

The costs of adjusting nominal prices (whatever they look like concretely) were shown in the previous chapters to provide a theoretical justification for nominal price rigidity and, accordingly, for the breakdown of the classical dichotomy. Taking this as a landmark, I analyse here the relation between menu costs and market structures. Notably, the relation between menu costs and (different types of) oligopoly markets.
As pointed out earlier[1], the microeconomic literature includes some recent contributions where menu costs are analysed within a strategically interactive setting[2]. Nonetheless, these neglect to distinguish between nominal and real

[1] See Chapter three.
[2] In Blanchard and Fischer (1989) as well, a simple Bertrand duopoly model with menu costs is briefly outlined at the end of Chapter 8, within the Section "Problems". The authors refer to Caminal (1987).

magnitudes. Moreover, nothing is said about the nature of the shocks. Yet, the distinction is not at all trivial. Nominal shocks, in fact, have real effects only in case of sluggish nominal adjustments. Whereas real disturbances have *always* real effects, irrespective of whether nominal prices are rigid or not. Accordingly, the presence of nominal friction, such as menu costs, seems to be far more crucial within a framework where monetary rather than real shocks are considered.

To preserve the theoretical relevance of menu costs I shall set up a model where real and monetary variables are clearly identified. Besides, I shall explicitly consider nominal disturbances. So, alterations of the state of the nature are due exclusively to nominally-based shocks. Real shocks are ruled out. In line with the established economic theory, nominal movements have real effects only if monetary prices turn out to be sticky.

2. A Bertrand duopoly model with menu costs

My aim is to investigate how (different degrees of) strategic interaction can affect rational price-setters' decisions about whether or not to adjust their nominal prices in response to a one-off *nominal* shock, when nominal price adjustments are costly. To this end, I consider a symmetric Bertrand duopoly with differentiated non-storable goods. Prices are simultaneously set in advance of trade and must be quoted in monetary terms. If either firm alters its quoted nominal price, it will incur a fixed menu cost, z (with $z \geq 0$). Both firms are supposed to be able to supply whatever quantity consumers demand when exchange takes place[3] (i.e., there are no capacity constraints). I also assume that all industries but the one under study are perfectly competitive. Such assumption has been added as to ensure that the real effects of money stem exclusively from duopolists' behaviour and not from nominal rigidities within other markets.

Caminal (1987)'s aim is, among other, to derive a *real* price adjustment rule within a tow-period duopoly game with asymmetric information.

With respect to the point above, I am very grateful to Prof. Stefano Torri, who suggested me the key elements of Caminal (1987) and provided me with the necessary information.

[3] Quantity adjustments are supposed to be costless. As mentioned in chapter two, costly quantity adjustments with menu costs are considered, among others, in Andersen (1994) and (1995) and in Lucke (1995). Costly quantity adjustments alone are treated in Ginsburg *et al.* (1991).

2.1 A non-linear demand structure

To start with, I consider the general case where no specific functional form is used to represent each duopolist's demand schedule, which, therefore, is written as:

(1)[4] $q_i(p_i, p_j)$ with $i \neq j$ and $i = 1,2$,

where q_i, p_i and q_j, p_j are the quantity demanded and the *real* price of good *i* and *j*, respectively; $\partial q_i / \partial p_i$ is assumed to be negative, whereas the sign of $\partial q_i / \partial p_j$ depends upon the nature of the goods. A positive (negative) $\partial q_i / \partial p_j$ implies goods are substitutes (complements). The absolute value of $\partial q_i / \partial p_j$ measures the cross-price effects[5]. I shall take it as an index of the degree of strategic interaction within the market.

Notice that the above demand function is expressed in real terms. It depends, in fact, on *real* prices. Letting *N* denote some exogenous nominal scale variable (henceforth nominal magnitudes are indicated by capital letters), nominal prices are defined as follows:

(2) $P_i = f(p_i, N)$;

equation (2) simply says that monetary prices' quotation depends both upon the "underlying" real prices as well as upon some relevant monetary index[6]. For simplicity, equation (2) can be specified as follows:

(2a) $P_i = Np_i \quad \Leftrightarrow \quad p_i = \dfrac{P_i}{N}$;

It is straightforward to see from (2a) that changes in the nominal scale variable, *N*, can affect the real price, p_i, and, consequently, each duopolist's demand function only if the nominal price, P_i, is rigid. Otherwise, if P_i fully and promptly adjusts to changes in *N*, the «classical dichotomy» between nominal and real variables will

[4] It is worth noticing that demand depends only on current real prices charged by the firms. Thus, consumers' speculation about future prices is ruled out. The function in (1) is supposed to be twice-continuously differentiable within the bounded region in price space where demands are positive.

[5] It makes sense to set $|\partial q_i / \partial p_j| < |\partial q_i / \partial p_i|$.

[6] In a more general setting, any nominal variable relevant for the "monetary side" of the economy.

hold[7]. As for the meaning of N, it can be interpreted as an exchange rate that allows to convert real magnitudes into nominal terms. Within a partial-equilibrium analysis, carried out here, the nominal scale variable can be thought of as the inflation rate or the level of nominal GNP. In case of a general equilibrium analysis, N can be any index related to the money stock, exogenously determined.

Each firm's average/marginal costs are assumed to be constant. Thus, firm i's (real) production costs can be written as:

(3) $c_i(q_i) = kq_i$.

For simplicity, k is normalized to zero[8].

The industry is assumed to be initially at its Bertrand-Nash (B-N) equilibrium configuration, which is given by the intersection of each duopolist's best-response functions. In order to ensure that these (i) intersect and (ii) the intersection point is unique the following inequality must hold[9]:

$$\partial^2\pi_i/\partial p_i^2 + \left|\partial^2\pi_i/\partial p_i \partial p_j\right| < 0 \qquad \forall \ (p_i, p_j) \text{ such that } q_i > 0;\ (i = 1,2; \neq j),$$

where π_i is the firm i's profit.

The initial symmetric equilibrium values of each duopolist's output, real price, and profit are denoted, respectively, as follows:

$$q_i^{BER},\ p_i^{BER} \text{ and } \pi_i^{BER} \equiv \pi_i\left(p_i^{BER}, p_j^{BER}\right) \qquad (i = 1,2; \neq j).$$

These magnitudes are in real terms. In line with the menu-cost literature, however, I have assumed that at the moment of price quotation (time 0) each firm announces its profit maximising price in nominal terms. The optimal nominal price corresponding to the initial B-N equilibrium is given by the following pricing rule[10]:

(4) ${}_0P_i^{BER} = p_i^{BER} N^e$,

---

[7] In the absence of any type of nominal rigidity, equation (2) turns out to be homogeneous of degree 1 in the nominal variable N.

[8] This simplification does not affect the conclusions, as k is time invariant in this model. Since all markets but the one under analysis are supposed to be perfectly competitive, nominal input prices are fully flexible.

Some minor implications of non-zero marginal costs are discussed in Appendix, at the end of the Chapter.

[9] Details and references are in Singh and Vives (1984), p. 552.

[10] The case of indexed nominal prices is ruled out, like in Mankiw (1985). See Chapter two for more details.

where ${}_0P_i^{BER}$ is the *ex-ante* nominal profit maximising price; p_i^{BER} is the "underlying" optimal real price, and N^e denotes firms' expectations about the nominal scale variable's value at the moment of exchange (time t). Since firms are identical and there is no reason to suppose asymmetric information about future realisations of N, N^e is the same for both firms.

2.2 The simultaneous decision problem

At the time trade takes place, if N^e turns out to be incorrect ($N^e \neq N_t$), namely if a nominal shock has occurred, all firms have to decide simultaneously as whether to adjust (action A) their previously quoted nominal price, ${}_0P_i^{BER}$, in response to the monetary shock, or not to adjust it (action R). Once the decision is taken, it is irreversible and becomes public knowledge.

By choosing (A), the firm incurs a menu cost, z, and can set its nominal price optimally again[11]. By choosing (R), the firm does not pay the menu costs and keeps its previously quoted nominal price fixed, i.e., rigid (hence the R to indicate non-adjustment). In this case, the underlying real price, p^{RIG}, will be:

(5) $$p^{RIG} = \frac{{}_0P^{BER}}{N_t}; \text{ or, equivalently, } \quad p^{RIG} = p^{BER}\delta, \text{ where } \delta = N^e\!/\!N_t.$$

Notice that δ, which is always strictly positive, can be viewed as an indirect measure of the nominal shock. For δ larger (smaller) than unity, then $N^e > N_t$ ($N^e < N_t$). Thus, the nominal shock is negative (positive), such as an unexpected money contraction (expansion). From (5) it is straightforward to see that:

(6) $$\delta \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} 1 \Leftrightarrow p^{RIG} \begin{Bmatrix} > \\ = \\ < \end{Bmatrix} p^{BER}.$$

To illustrate the simultaneous decision problem outlined above, consider the following 2x2 payoff matrix (Figure 1), where rows refer to firm 1's decisions and columns to firm 2's.

[11] It means the firm can stay on its best-response function.

		Firm 2	
		Adjustment (A)	Rigidity (R)
Firm 1	Adjustment (A)	$\pi^{A,A} - z$; $\pi^{A,A} - z$	$\pi^{A,R} - z$; $\pi^{R,A}$
	Rigidity (R)	$\pi^{R,A}$; $\pi^{A,R} - z$	$\pi^{R,R}$; $\pi^{R,R}$

Figure 1: decision problem and payoffs

(A,A) and (R,R) cells correspond to the case of symmetric behaviour (i.e., firms take the same decisions). (A,R) and (R,A) cells correspond to the case of asymmetric behaviour.

(i) In (A,A) cell, both firms pay the menu costs and adjust their quoted nominal prices. Consequently, the nominal shock is "neutralised". The initial equilibrium configuration (in real terms) does not change. Each duopolist's payoff is $\pi_i^{A,A} - z$, (notice that $\pi_i^{A,A}$ is equal to π_i^{BER}).

(ii) In (R,R) cell, neither firms incur the menu costs and monetary prices are kept fixed. Under such circumstances, nominal price rigidity is total. Each duopolist's payoff is $\pi_i^{R,R}$.

(iii) In (A,R) cell[12], one firm pays the menu costs and can set its nominal price optimally, given its rival's decision. The other, instead, does not pay the menu costs and keeps its nominal price fixed. Nominal rigidity is therefore partial. The payoff of the adjusting firm $\pi_i^{A,R} - z$. The payoff of the non-adjusting firm is $\pi_i^{R,A}$.

According to the definition of B-N equilibrium, it is straightforward to establish that[13]:

(7) (A,A) is a B-N equilibrium when: $\pi_i^{A,A} - \pi_i^{R,A} \geq z \Leftrightarrow \Delta\pi_i^{R,A} \geq z$;

(8) (R,R) is a B-N equilibrium when: $\pi_i^{A,R} - \pi_i^{R,R} \leq z \Leftrightarrow \Delta\pi_i^{R,R} \leq z$;

[12] The same holds for (R,A) cell, *mutatis mutandis*.
[13] Details in Appendix at the end of the Chapter.

(9) (A,R) is a B-N equilibrium when: $\Delta\pi_i^{R,A} < z < \Delta\pi_i^{R,R}$.

(First superscripts refer to firm *i*'s actions).

$\Delta\pi_i^{R,A}$ can be thought of as firm *i*'s cost of rigidity, when firm *j* adjusts; whereas $\Delta\pi_i^{R,R}$ as firm *i*'s cost of rigidity, when firm *j* keeps its price fixed.

A close examination of $\pi_i^{R,A}$, $\pi_i^{R,R}$, and $\pi_i^{A,R}$ reveals that:

$$\pi_i^{R,A} = \pi_i\left(p_i^{RIG}, p_j\left(p_i^{RIG}\right)\right);$$

$$\pi_i^{R,R} = \pi_i\left(p_i^{RIG}, p_j^{RIG}\right);$$

$$\pi_i^{A,R} = \pi_i\left(p_i\left(p_j^{RIG}\right), p_j^{RIG}\right).$$

Given the information above, firm *i*'s costs of rigidity, when the rival chooses in turn to adjust and not to adjust its nominal price can be written as follows

$$\Delta\pi_i^{R,A} = \pi_i\left(p_i^{BER}, p_j^{BER}\right) - \pi_i\left(p_i^{RIG}, p_j\left(p_i^{RIG}\right)\right);$$

$$\Delta\pi_i^{R,R} = \pi_i\left(p_i\left(p_j^{RIG}\right), p_j^{RIG}\right) - \pi_i\left(p_i^{RIG}, p_j^{RIG}\right).$$

According to the above expressions, it can be said that $\Delta\pi_i^{R,R}$ is always positive[14]; whereas the sign of $\Delta\pi_i^{R,A}$ cannot be *a priori* determined. It may be positive, as well as negative. This result proves to be particularly interesting. It suggests that, at least in principle, even with zero menu costs firm-specific nominal price rigidity can arise.

Consider conditions (7)-(9). Setting z equal to zero, inequality in (8) is never met. Consequently, (R,R), i.e., total nominal price rigidity, cannot be a B-N equilibrium outcome under the assumption of zero menu costs. Now, for a positive $\Delta\pi_i^{R,A}$, (A,A) represents the B-N equilibrium. But, if $\Delta\pi_i^{R,A}$ turns out to be negative, inequality in (7) will be no longer satisfied. As a result, condition (9) will be met and partial nominal price rigidity, i.e. (A,R) and/or (R,A) will be the optimal duopolists' response to the monetary shock. Despite the absence of "physical" nominal barriers there may be some strategically interactive price-setters who prefer to keep their monetary prices fixed. This result clearly depends on the fact that the private cost of

[14] For definition, $p_i\left(p_j^{RIG}\right)$ is firm *i*'s best response (i.e. firm *i*'s profit maximising price) to its rival's price level, p_j^{RIG}.

rigidity, $\Delta\pi_i^{R,A}$, can be negative. In this regard, it is worthwhile remarking that neither in monopoly nor in monopolistic competition the private cost of rigidity is negative[15]. That is why within this class of imperfectly competitive markets menu costs (i.e., the cost of flexibility) must be strictly positive for firm-specific nominal stickiness to be privately optimal. I shall revert to this point later.

Since further insights can hardly be gained from the general treatment, an explicit functional representation of $q_i(p_i, p_j)$ must be chosen. Notably, a linear demand function will be considered. It allows to present my findings in an effective and easily understandable fashion.

2.2 A linear demand structure

Each duopolist's demand schedule is assumed to be a linear function in real prices, p_i and p_j. Thus,

(10) $q_i = \alpha - \beta p_i + \eta p_j$ with $i \neq j$ and $i, j = 1{,}2$

where α and β are positive constants, while the sign of η depends on the nature of the goods[16]. The cross-price effects is here measured by the absolute value of η[17], which, therefore, is taken as a measure of the degree of strategic interaction. In particular, for $\eta = 0$ (i.e., zero cross-price effects) each firm behaves as a monopolist.

Each duopolist's reaction curves reads:

$$p_i(p_j) = \frac{\alpha + \eta p_j}{2\beta}, \qquad \text{with } i \neq j \text{ and } i = 1{,}2 .$$

Consequently, the initial B-N equilibrium configuration is:

$$\left(q_i^{BER}; p_i^{BER}\right) = \left(\frac{\alpha\beta}{2\beta - \eta}; \frac{\alpha}{2\beta - \eta}\right), \quad \pi_i^{BER} = \frac{\alpha^2 \beta}{(2\beta - \eta)^2}.$$

From each duopolist's demand function and reaction curve, it can be derived[18] that:

[15] See, among others, Weiss and Sheshinski (1977), Mankiw (1985), Ball and Romer (1989, 1990). See also Chapter two.

[16] For η strictly larger (smaller) than zero goods are substitutes (complements).

[17] Notice that $|\eta| < \beta$.

[18] Details in Appendix, at the end of the Chapter.

$$\pi_i^{R,R} = \pi_i^{BER}\left[1+(1-\delta)\left(1-\frac{\eta}{\beta}\right)\right]\cdot\delta;$$

$$\pi_i^{A,R} = \pi_i^{BER}\left[1-\frac{\eta}{2\beta}(1-\delta)\right]^2;$$

$$\pi_i^{R,A} = \pi_i^{BER}\left[1+(1-\delta)\left(1-\frac{\eta^2}{2\beta^2}\right)\right]\cdot\delta.$$

Now, substituting the above expressions into (7)-(8), the conditions according to which (A,A), (R,R), and (A,R) represent, in turn, a B-N equilibrium become:

(7a) (A,A): $\pi_i^{BER}(1-\delta)\cdot\left[1-\delta\cdot\left(1-\frac{\eta^2}{2\beta^2}\right)\right]\geq z;$

(8a) (R,R): $\pi_i^{BER}(1-\delta)^2\cdot\left(1-\frac{\eta}{2\beta}\right)^2\leq z;$

(9a) (A,R): $\pi_i^{BER}(1-\delta)\cdot\left[1-\delta\cdot\left(1-\frac{\eta^2}{2\beta^2}\right)\right]<z<\pi_i^{BER}(1-\delta)^2\cdot\left(1-\frac{\eta}{2\beta}\right)^2.$

Being the payoffs state-contingent, the above conditions depend on:

(i) the sign and size of nominal disturbance, indirectly identified by δ values;

(ii) the relative size of menu costs, z;

(iii) the market features (i.e., type of goods and degree of strategic interaction), embodied both in the sign and in the absolute value of η.

The LHS expressions in (7a) and (8a) are nothing else but $\Delta\pi_i^{R,A}$ and $\Delta\pi_i^{R,R}$, respectively. As pointed out earlier, the former can be either positive or negative; the latter, instead, is always larger than zero.

Treating η as a fixed parameter, the menu cost z can be expressed as a fraction λ of π_i^{BER} (with $0\leq\lambda<1$).

3. The results

In order to determine the solutions of the game-theoretic problem outlined in the previous section we need to study inequalities in (7a) and (8a). Condition (9a), in fact, is simply the reverse of conditions (7a) and (8a). Treating η and β as parameters, inequality in (7a) is satisfied for

(10)[19] $\delta \leq 1-\delta^{*}_{A,A}$ and $\delta \geq 1+\delta^{**}_{A,A}$,

where

$$\delta^{*}_{A,A}=\frac{1}{2\beta^2-\eta^2}\left[\beta\sqrt{\frac{\eta^4}{4\beta^2}+2\lambda\left(2\beta^2-\eta^2\right)}-\frac{\eta^2}{2}\right],$$

$$\delta^{**}_{A,A}=\frac{1}{2\beta^2-\eta^2}\left[\beta\sqrt{\frac{\eta^4}{4\beta^2}+2\lambda\left(2\beta^2-\eta^2\right)}+\frac{\eta^2}{2}\right].$$

As for inequality in (8a), it is met for

(11)[20] $1-\delta^{*}_{R,R} \leq \delta < 1$ and $1 < \delta \leq 1+\delta^{*}_{R,R}$,

where:

$$\delta^{*}_{R,R}=\frac{2\beta}{2\beta-\eta}\sqrt{\lambda}.$$

Inspection of (10) and (11) allows to draw the following conclusions.

3.1 Zero menu costs and firm-specific nominal price rigidity

Setting λ (i.e., the menu cost) equal to zero yields

$$\delta^{*}_{A,A}=0,$$

$$\delta^{**}_{A,A}=\frac{\eta^2}{2\beta^2-\eta^2},$$

$$\delta^{*}_{R,R}=0.$$

Given the above values, according to (10) and (11), it turns out that:

- (A,A) is a B-N equilibrium outcome, i.e. both duopolists adjust their nominal prices, in case of positive shocks (i.e., $\delta<1$) and in case of relatively large negative shocks, namely $\delta \geq 1+\dfrac{\eta^2}{2\beta^2-\eta^2}$;

---

[19] The results are not symmetric around one.

[20] For $\delta=1$ there is no shock. So, the decision problem would not rise.

- (A,R) or (R,A), i.e. asymmetric price adjustments, are an equilibrium outcome for relatively small negative shocks (namely, for $\delta < 1 + \frac{\eta^2}{2\beta^2 - \eta^2}$ condition (9a) is met);
- (R,R) is never a B-N equilibrium outcome, i.e., condition (8a) is never met.

Notice that $\frac{\eta^2}{2\beta^2 - \eta^2}$ is increasing in (the absolute value of) η. Thus, as the degree of strategic interaction between price-setters goes up, the range of negative shocks for which asymmetric behaviour represents an equilibrium response rises.

This result suggests that the assertion that «imperfect competition, [...], does not in itself cause any nominal rigidities»[21] is not necessarily true. Strategic interaction can in and of itself generates firm-specific nominal price rigidity and, consequently, leads to failure of the classical dichotomy[22]. A graphical intuition of the result is given in the Appendix, at the end of the Chapter.

3.2 Symmetric and asymmetric multiple equilibria

Multiple equilibria, both symmetric[23] and asymmetric, can arise. With respect to this point, notice that the LHS expressions in (7a) and (8a), which I shall denote by $\Delta\pi_i^{R,A}$ and $\Delta\pi_i^{R,R}$, respectively, are the equations of two convex parables. Symmetric (asymmetric) multiple equilibria possibly arise when parable (7a) is above (below) parable (8a), i.e., $\Delta\pi_i^{R,A} \geq \Delta\pi_i^{R,R}$ ($\Delta\pi_i^{R,A} < \Delta\pi_i^{R,R}$). The comparison of the two parables yields

[21] See Andersen (1994), p. 43.

[22] Hansen *et al.* (1996) draw similar conclusions as regards *real* (rather than nominal) prices. Specifically, they show that asymmetric adjustments in real prices may represent the equilibrium response of strategically interactive price-setters to (small) negative real shocks. Notice, however, that Hansen *et al.* (1996) findings do not imply the failure of the classical dichotomy. By definition, the classical dichotomy breaks down when nominal movements (i.e., nominal shocks) affect real magnitudes. As a matter of logic (because of the zero-degree homogeneity property in nominal variables held by individual demand and supply functions), for money to have real effects, nominal rather than real price rigidity is needed.

[23] Symmetric multiple equilibria are found out to occur also within monopolistically competitive markets. See Ball and Romer (1990); see also Chapter two.

for $\eta > 0$: $\Delta\pi_i^{R,A} \geq \Delta\pi_i^{R,R}$ if $\delta < 1$ and $\delta \geq 1 + \frac{2\eta}{4\beta - 3\eta}$;

for $\eta < 0$: $\Delta\pi_i^{R,A} \geq \Delta\pi_i^{R,R}$ if $1 - \frac{2|\eta|}{4\beta + 3|\eta|} \leq \delta < 1$.

The results are contingent to the nature of the goods.

i. For substitute goods:

- symmetric multiple equilibria can occur for positive nominal shocks (i.e., $\delta < 1$) and in case of large negative shocks (i.e., $\delta \geq 1 + \frac{2\eta}{4\beta - 3\eta}$). Consequently, asymmetric multiple equilibria can arise only for $\delta < 1 + \frac{2\eta}{4\beta - 3\eta}$.

Notice that $\frac{2\eta}{4\beta - 3\eta}$ is increasing in η. Thus, as the degree of strategic interaction between price-setters goes upwards, the possibility of symmetric (asymmetric) multiple equilibria to occur with negative shocks becomes lower (higher), *ceteris paribus*.

ii. For complement goods:

- symmetric multiple equilibria can arise only in case of relatively small positive shocks (i.e., $1 - \frac{2|\eta|}{4\beta + 3|\eta|} \leq \delta < 1$). Asymmetric multiple equilibria possibly arise in case of negative shocks and for large positive shocks, (i.e., $\delta < 1 - \frac{2|\eta|}{4\beta + 3|\eta|}$).

Since $\frac{2|\eta|}{4\beta + 3|\eta|}$ is increasing in (the absolute value of) η, the chance for having symmetric (asymmetric) multiple equilibria with positive shocks rises (decreases) when the degree of strategic interaction between price-setters goes upwards, *ceteris paribus*.

iii. For η equal to zero:

- if strategic interaction between price-setters is absent and each behaves as a monopolist, situations of multiple equilibria, either symmetric or asymmetric, will disappear. Thus, the model generates Mankiw's (1985) as a special case.

Findings in points (i) and (ii) imply that

a) asymmetric multiple equilibria (i.e., asymmetric nominal price adjustments) are more likely to occur when goods are complement rather than substitute, irrespective of the absolute value taken by η. The reverse applies to symmetric multiple equilibria. Such result evokes the idea of "strategic complementarity" and "strategic substitutability" in *real* price movements for substitute and complement products, respectively.
b) Duopoly nominal price adjustments can differ according to whether the disturbances are positive or negative. Notably, for substitute goods, asymmetric adjustments, (A,R) and (R,A), are an equilibrium response exclusively to negative shocks. When disturbances are of opposite sign, duopoly price-setters behave symmetrically. Either both adjust their nominal prices, or both keep them fixed.

In order to put all the foregoing results together and to highlight the main features of the "duopoly nominal price adjustment rule", inequalities (7a) and (8a) have been plotted in the (δ,λ) space. Figures 2 and 3, have been drawn for $\eta=+0.5$ and $\eta=-0.5$, respectively, and for $\beta=1$.

(FIGURE 2 and 3 at the end of the chapter).

3.3 Negative shocks and asymmetric price adjustments

In the previous section it has been found out that asymmetric equilibria can arise (mainly) when shocks are negative. In case of positive shocks, price-setters' adjustment decisions are (very likely to be) symmetric. It implies that the price adjustment rule is contingent to the sign of nominal disturbances. The rationale behind such finding can be grasped as follows. Suppose that firm j pays the menu cost and adjusts its nominal price. The choice for firm i is between (R,A) and (A,A). Firm i will prefer the former to the latter outcome, i.e., (R,A) will turn out to be a B-N equilibrium, if the private cost of rigidity, $\pi_i^{A,A} - \pi_i^{R,A} \equiv \Delta\pi_i^{R,A}$, is smaller than the cost of flexibility, z. As pointed out earlier, when shocks are positive $\pi_i^{A,A}$ is always strictly larger than $\pi_i^{R,A}$, (irrespective of the type of goods). As a result, z must be relatively large for firm i to choose (R,A). Notice, however, that the higher the menu costs, the lower the rival's incentive to choose (A). It turns out that asymmetric behaviours can hardly be B-N equilibrium outcomes. Each duopolist's best responses to a positive shock (tend to) mirror his/her rival's decisions and multiple symmetric equilibria possibly arise. On the contrary, at the occurrence of negative disturbances, $\pi_i^{A,A}$ may be smaller than $\pi_i^{R,A}$. If so, it implies a private gain from rigidity. Consequently, relatively large menu costs are not needed for firm i to choose (R). Strategically stable asymmetric equilibria can, therefore, arise.

4. Conclusions

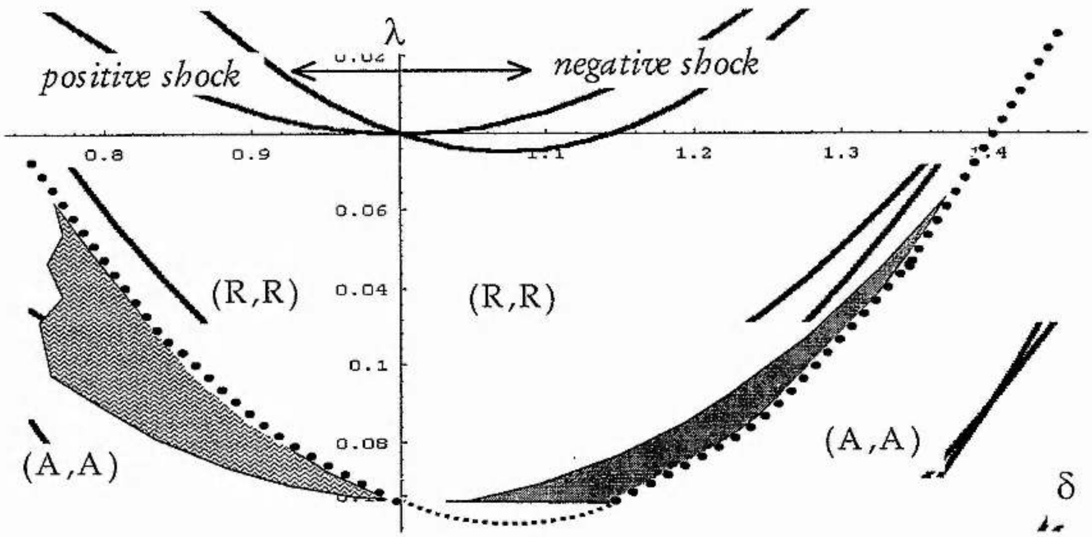
In a Bertrand differentiated-good duopoly the price-setters optimal pricing responses to a single nominal shock have been derived. The nominal price adjustment rule turns out to be much more sophisticated than the one within a market where strategic interaction is absent. In particular:

i) nominal price adjustments vary according to the sign of the nominal shock;

ii) symmetric as well as asymmetric multiple equilibria may occur;

iii) "physical nominal barriers" (such as menu costs) may not be necessary for nominal rigidity to arise.

These results depend not just on the sign and size of nominal shock and on the relative size of menu costs, but also on the market features, notably on the degree of strategic interaction between price-setters.



FIGURES 2 AND 3

Legend: ——— $\lambda=(1-\delta)^2\left(1-\frac{\eta}{2}\right)^2$

.... $\lambda=(1-\delta)\left[1-\delta\left(1-\frac{\eta^2}{2}\right)\right]$

= *Multiple* symmetric *equilibria: (A,A), (R,R)*

= *Multiple* asymmetric *equilibria: (A,R), (R,A)*

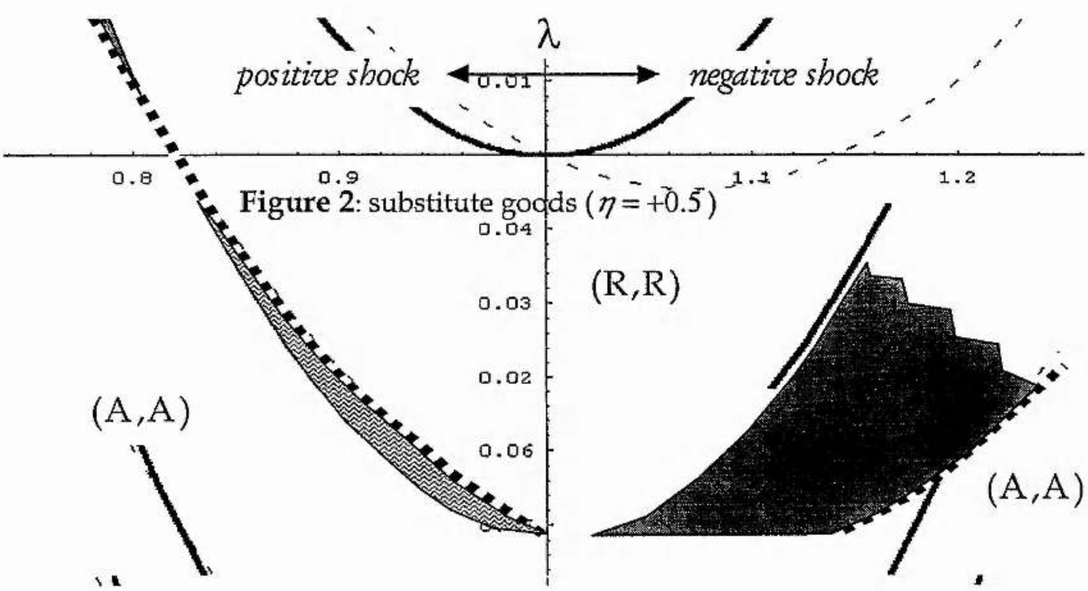


Figure 2: substitute goods ($\eta=+0.5$)

Figure 3: complement goods ($\eta=-0.5$)

Appendix to Chapter 4

1. Some minor implications of non-zero marginal costs

The main results of the model are fully unaffected by the zero marginal cost simplification. However, it may be interesting to examine what happens if non-zero marginal costs are considered. We shall focus particularly on the case of positive shocks. Under such circumstances, nominal price rigidity implies a contraction in the underlying real prices. The larger the positive shock, the stronger the real price contraction. At least in principle, it might also occur that real prices turn out to be below the marginal costs. Under a similar scenario, nominal price rigidity would arise as a Nash equilibrium only in case of relatively high menu cost.

2. Derivation of (7)-(9)

To derive condition (7)-(9) consider the following.

a) Under the circumstances firm *j* is adjusting her nominal price, firm *i* will choose (A,A) as an equilibrium strategy if $\pi^{A,A} - z \geq \pi^{R,A}$. Otherwise, firm *i'* will choose (R,A).

b) Under the circumstances firm *j* is not adjusting her nominal price, firm *i* will choose (R,R) as an equilibrium strategy if $\pi^{R,R} \geq \pi^{A,R} - z$. Otherwise, firm *i* will opt for (A,R).

Because of symmetry, $\pi^{R,A} = \pi^{A,R}$. Besides, the above holds for firm *j*, *mutatis mutandis*.

3. Derivation of (7a)-(9a)

Firm i's reaction function reads

$$p_i(p_j) = \frac{\alpha + \eta p_j}{2\beta} \qquad\qquad i = 1,2; \neq j.$$

Accordingly,

$$\left(q_i^{BER}, p_i^{BER}\right) = \left(\frac{\alpha\beta}{2\beta - \eta}; \frac{\alpha}{2\beta - \eta}\right).$$

In case of (A,A), i.e., both firms adjust, the classical dichotomy will hold. So

$$q_i^{BER} = q_i^{A,A} \text{ and } p_i^{BER} = p_i^{A,A}.$$

In case of (R,R):

$$q_i^{R,R} = q_i^{A,A}\left[1 + \left(1 - \frac{\eta}{\beta}\right)(1-\delta)\right] \quad \text{and} \quad p_i^{R,R} = \delta p_i^{A,A};$$

in case of (A,R):

$$q_i^{A,R} = q_i^{A,A}\left[1 - \frac{\eta}{2\beta}(1-\delta)\right] \quad \text{and} \quad p_i^{A,R} = p_i^{A,A}\left[1 - \frac{\eta}{2\beta}(1-\delta)\right];$$

in case of (R,A):

$$q_i^{R,A} = q_i^{A,A}\left[1 + \left(1 - \frac{\eta^2}{2\beta^2}\right)(1-\delta)\right] \quad \text{and} \quad p_i^{R,A} = \delta p_i^{A,A}.$$

Using the above information, it is straightforward to establish that

$$\text{(I)} \qquad \pi_i^{R,R} \equiv \pi_i\left(p_i^{RIG}, p_j^{RIG}\right) = \pi_i^{BER}\left[1 + \left(1 - \frac{\eta}{\beta}\right)(1-\delta)\right]\delta;$$

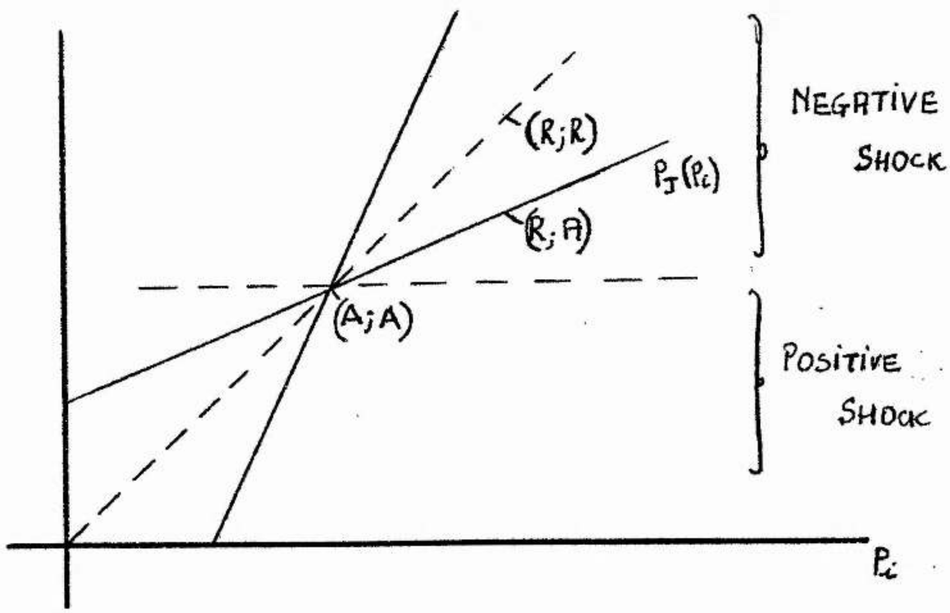
$$\text{(II)} \qquad \pi_i^{A,R} \equiv \pi_i\left(p_i\left(p_j^{RIG}\right), p_j^{RIG}\right) = \pi_i^{BER}\left[1 - \frac{\eta}{2\beta}(1-\delta)\right]^2;$$

$$\text{(III)} \qquad \pi_i^{R,A} \equiv \pi_i\left(p_i^{RIG}, p_j\left(p_i^{RIG}\right)\right) = \pi_i^{BER}\left[1 + \left(1 - \frac{\eta^2}{2\beta^2}\right)(1-\delta)\right]\delta.$$

Given (I)-(III), it is straightforward to derive conditions (7a)-(9a).

4. Graphical intuition of the (A,R) result in case of zero menu costs

As formally proved in Chapter 4, within a strategic interaction setting for (partial) nominal price rigidities to arise "physical" nominal barriers may not be needed. Notably, asymmetric adjustments, i.e. (A,R) or (R,A), can turn out to be a B-N equilibrium outcome, regardless the amount of menu costs. The graph below, which is drown considering substitute goods[24], may help to understand the reason. Let us consider the case firm j responds to a negative shock by adjusting its nominal price (i.e., it remains on its best-response function). From firm i's perspective, the choice is between (A,A) and (R,A). As formally proved in Chapter 4 and shown by the Figure below, the sign of $\Delta\pi_i^{R,A} \equiv \pi_i^{A,A} - \pi_i^{R,A} \equiv \pi_i\left(p_i^{BER}, p_j^{BER}\right) - \pi\left(p_i^{RIG}, p_j\left(p_i^{RIG}\right)\right)$ may be negative. That is why firm i may opt for not adjusting its nominal prices even in the absence of menu costs[25].



[24] Same conclusions hold for complement goods.

[25] In the absence of menu costs, (R, R) outcome can not be a stable equilibrium, since each firm has an incentive to deviate from it and to stay on its best-response function. From this perspective, menu costs may be viewed as some type of "collusive" cost (i.e., costs to grant a stable collusion).